THE EMPIRE JOURNAL OF EXPERIMENTAL AGRICULTURE

VOL. XXIX · NO. 113 · JANUARY 1961

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OXFORD

AT THE CLARENDON PRESS: 1961

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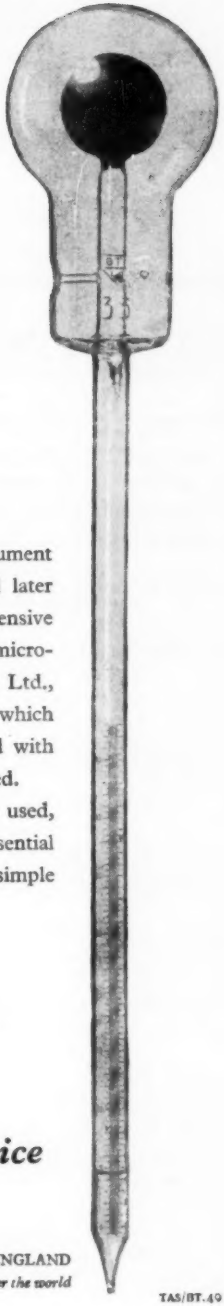

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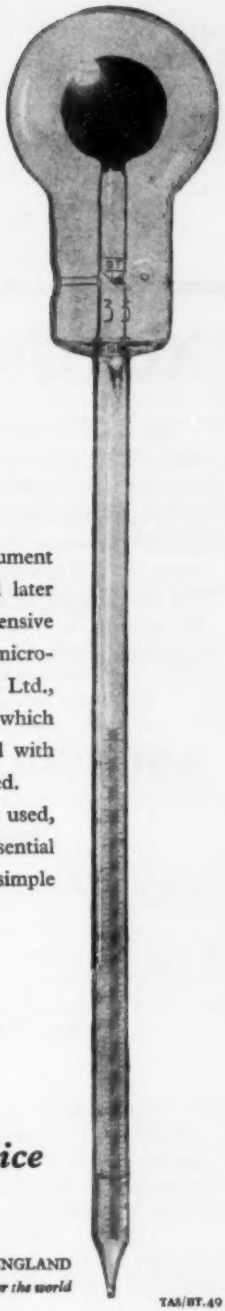

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GROWTH AND YIELD OF COTTON SPRAYED WITH D.D.T. IN EAST AND NORTH UGANDA

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(*Empire Cotton Growing Corporation, Namulonge, Uganda*)

Summary

Studies were made at six variety-trial centres in the Eastern and Northern Provinces of Uganda, where both sprayed and unsprayed cotton trials were conducted. At three centres spraying with D.D.T. 8 weeks after planting was correlated with increases in yields of 93, 78, and 57 per cent. respectively. At the other three centres reductions in the yield of sprayed cotton of 5, 6, and 21 per cent. were observed.

Growth records indicated that spraying reduced both leaf tattering due to various insects, and the percentage of fruiting bodies shed. At four centres the sprayed crop was set earlier; unsprayed plants showed growth at a high rate compared with the sprayed plants, but at only one centre did this result in sufficient crop to equal the yield of the sprayed plants. At the other two centres the rate of growth was similar in both trials.

It is suggested that where environmental factors do not favour continued crop formation, spraying is likely to give appreciable yield increases.

INSECTICIDAL control of cotton pests (in particular those of the Mirid complex) at a number of peasant holdings in the Eastern and Northern Provinces of Uganda was investigated by the Department of Agriculture during the 1957–8 season. It was found that spraying with a D.D.T. formulation resulted in an increase in yield [1], and it was decided to extend these observations, commencing in 1958–9, at seventeen centres on duplicated cotton variety trials, one of which was sprayed, the other left unsprayed.

Considerable data exist on the effects of applications of insecticides on growth and yield of BP52 cotton at Namulonge in Buganda Province [2, 3]. An investigation into the effects of spraying at a number of centres in the Eastern and Northern Provinces was made, to assess the growth of sprayed and unsprayed S47 cotton, with special reference to fruiting behaviour and yield, and to attempt to correlate this with insect attack. Results are presented for individual centres, and a more comprehensive account is given in subsequent discussion.

Materials and Methods

All the variety trials were laid out to a 5×5 latin square design, individual plot size being 1/66 acre. The variety S47 (Serere) was common to both sprayed and unsprayed trials. At most centres the two trials were separated by a fallow crop. Because of the nature of the experiment differences due to variations in soil fertility cannot be unequivocally separated from the effects of spraying.

On sprayed trials 1 lb. D.D.T. (25 per cent. miscible liquid)/acre was applied as a low-volume spray (8 to 10 gallons/acre) four times

[Empire Journ. of Exper. Agric., Vol. 29, No. 113, 1961.]

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at 10-day intervals. Spraying was commenced 56±4 days after planting and was thus concluded by 13 weeks after planting. The following detailed observations were made at each trial at 9–10 (i.e. as soon after the commencement of spraying as possible), 14–15, 19–20, and 25–26 weeks after planting:

(i) The degree of leaf tattering, caused by *Lygus* spp., on the top four expanded leaves borne on the main-stem [3].
(ii) Height and number of nodes on main-stem.
(iii) Length and total number of nodes on sympodial branches borne on the main-stem.
(iv) The position and number of fruiting points. Presence or absence of fruiting bodies was noted, and where present these were classified as buds (including flowers), or bolls (including husks and damaged bolls).

These observations were made on a ten-plant sample, two plants being chosen at random from the central row of each plot of S47 in every trial. Successive observations were made on the same plants. In the Tables which follow (except Table 1) results are the mean values for ten plants. Where statistical significance has been determined the *t* test has been used.

Results

Consideration of Individual Trials

Nakabango, Busoga (about 6 miles north of Jinja). The soil is an extremely fertile reddish loam, free-draining, and with a good crumb structure [4]. Rainfall distribution is bimodal, the second peak being the lower and less pronounced of the two (Fig. 1). Both trials were planted on 4 June 1958 and early-season rainfall was good. From weeks 10–18 after planting rainfall, as measured over 3-week periods, was below the minimum expectation at 1:1 confidence limits [5, 6].

The sprayed trial yielded 5 per cent. less than the unsprayed trial (Table 1). Insect attack as indicated by leaf tattering (Table 2) was moderate early in the season, but fell to a low level after 15 weeks.

TABLE 1. *The Yield (lb. seed cotton/acre) of S47 (Serere) in Sprayed and Unsprayed Trials in 1958–9, and the Average Yields of this Cotton over the Last Five Years at the Same Centres.*
(Std. error of the mean of five plots per trial is quoted.)

Site	1958–9		Difference due to spraying	1953–8 average*
	Sprayed	Unsprayed		
Nakabango	1,154±25·3	1,210±32·4	−56	1,593
Kumi	1,690±108·2	948±58·8	+742	821
Serere	1,530±100·8	975±147·0	+555	1,334
Aduku	1,287±104·5	1,369±67·1	−80	1,268
Ngetta	1,181±81·7	611±35·0	+570	866
Gulu	792±49·3	1,003±29·3	−211	917

* Data refer to unsprayed trials except for Serere where only sprayed trials have been conducted over this period.

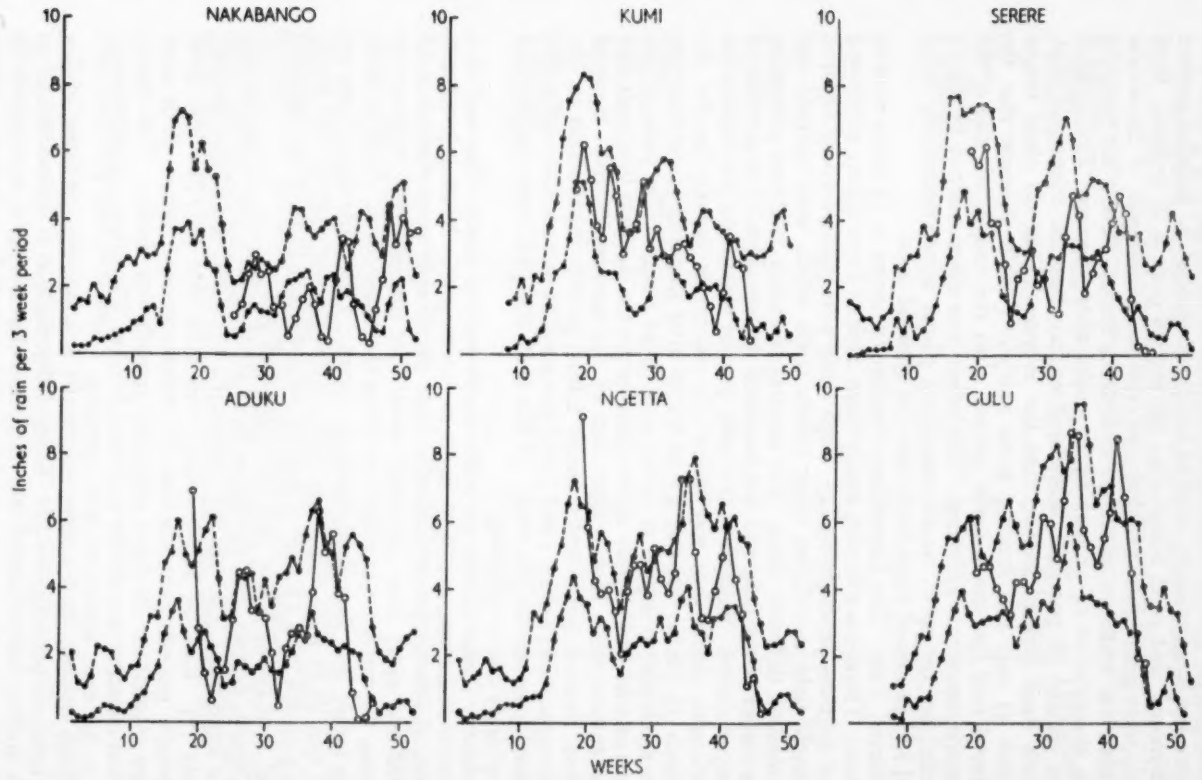

FIG. 1. 1:1 confidence limits for 3-week moving totals of rainfall at the six variety-trial centres. Broken lines give limits and solid lines the actual rainfall over the 1958–9 cotton season.

Kumi, Teso (about 30 miles north-west of Mbale). The soil at this centre is a brown, sandy loam of low productivity [4]. Rainfall pattern is bimodal, and as at Nakabango the second peak is ill defined. Both trials were planted on 22 April and over the greater part of the season rainfall was within or above the confidence limits. Severe leaf tattering was observed at 14–15 and 19–20 weeks after planting. The sprayed trial yielded 78 per cent. more seed cotton than the unsprayed trial, which itself yielded higher than the average. Data on plant height (Table 5) and the fruiting point analysis (Table 3) show that the sprayed trial had made better growth than the unsprayed trial at the commencement of spraying. This effect was more marked by 14–15 weeks, but by 19–20 weeks unsprayed plants were significantly taller and had produced more buds than the sprayed ones.

Serere, Teso. The Experiment Station at Serere is 35 miles west of Kumi. The soil is a brown, sandy loam derived from quartz schist and is of medium productivity [4]. Both trials were planted on 24 April in a single field containing other cotton trials which were sprayed and planted on different dates. The unsprayed variety trial was planted at one corner of the field and was bordered on two sides by large bulks of sprayed cotton. Rainfall in the early part of the season was within the confidence limits, but was below the minimum expectation for the periods 13–16, 20–22, and 27–30 weeks after planting. Leaf tattering was moderate to severe at 14–15 and 19–20 weeks. The yield of the sprayed trial was slightly above the average for the past five years and was 57 per cent. higher than that of the unsprayed trial. Sprayed cotton showed significantly better initial growth than cotton in the unsprayed trial (Tables 3 and 5) and it is possible that a fertility difference existed between the two trials. If this is so, the yield response may not be entirely due to spraying.

Aduku, Lango (about 22 miles south-west of Lira). The soil is a lateritic red loam, relatively high in exchangeable bases [7]. Cotton yields at this centre are generally high. Both trials were planted on 28 April and apart from dry spells soon after planting, and from 27–30 weeks, the rainfall was within or above the expectation. Leaf tattering was rather less than that found at Serere. Yield differences between the two trials were negligible. The fruiting point analysis and main-stem height data (Tables 3 and 5) indicate that initially the sprayed trial grew rather better than the unsprayed one.

Ngetta, Lango. Ngetta farm, 4 miles north of Lira, lies in the shadow of a large rock. The soil type is lateritic red loam, of medium productivity [7]. Rainfall in the season was such that only the last three 3-weekly periods gave less than the minimum expectation. Both trials were planted on 28 April and early growth was similar. The degree of leaf tattering was similar to that at Aduku. There was a yield increase of 93 per cent. associated with spraying.

Gulu, Acholi. Soil type at this centre is a lateritic red loam, of low to medium productivity [7]. Rainfall distribution is unimodal and in the 1958–9 cotton season was less than the minimum expectation in only one 3-weekly period. Leaf tattering was slight early in the season

TABLE 2. *Leaf-tattering Grade at Different Trials at Intervals throughout the Season. The Maximum Possible Score is 16·0*

	9–10 weeks	*14–15 weeks*	*19–20 weeks*	*25–26 weeks*
Nakabango				
Sprayed	7·5	1·0	0·4	not taken
Unsprayed	7·0	4·7	2·2	
	n.s.	n.a.[1]	n.a.[1]	
Kumi				
Sprayed	0	4·1	15·1	5·1
Unsprayed	0	8·7	10·5	5·3
	n.a.	†	†	n.s.
Serere				
Sprayed	0·3	7·1	8·3	1·1
Unsprayed	0·2	10·2	11·3	3·4
	n.a.	•	n.s.	n.s.
Aduku				
Sprayed	0·4	1·9	5·5	3·7
Unsprayed	1·6	8·8	10·3	3·9
	n.a.	†	†	n.s.
Ngetta				
Sprayed	0·7	5·0	11·4	7·8
Unsprayed	0·1	8·4	11·7	5·4
	n.a.	•	n.s.	n.s.
Gulu				
Sprayed	0·7	1·0	12·4	5·5
Unsprayed	0·4	6·7	14·6	5·5
	n.a.	n.a.[1]	n.s.	n.s.

n.a. = not analysed.
n.a.[1] = results not analysed because of large numbers of zero values for sprayed plants.
n.s. = difference not significant.
• = difference significant at $P = 0{\cdot}05$.
† = ,, ,, ,, $P = 0{\cdot}01$.

but severe by 19–20 weeks (i.e. about 6 weeks after spraying had stopped). The sprayed trial yielded 21 per cent. lower than the unsprayed one, but data on height and fruiting point production indicate that unsprayed plants grew considerably better than the sprayed ones late in the season (see Tables 3 and 5). This fact and the observed slow initial development of the plants at this centre are discussed later.

General Discussion

Leaf Tattering and Shedding

Leaf tattering was reduced on treated plants at all centres by the 14–15-week stage (i.e. when spraying had been discontinued), but this effect disappeared in three trials by the 19–20-week stage, and in all trials by the end of the season (see Table 2).

TABLE 3. *Fruiting-point Analysis from Six Trials at Intervals throughout the 1958–9 Season.* (*Significant differences between trials at the P = 0·05, 0·01, and 0·001 levels are shown by* *, †, *and* ‡ *respectively*)

NAKABANGO

	9–10 weeks	14–15 weeks	19–20 weeks	25–26 weeks
		Total fruiting points		
Sprayed	4·5	56·2	not measured	
Unsprayed	3·2	67·1		
	n.s.	n.s.		
		Bolls held (including husks)		
Sprayed	nil	5·8	9·4	9·1
Unsprayed	nil	5·0	14·3	12·3
		n.s.	*	n.s.
		Buds and flowers held		
Sprayed	2·9	40·2	3·8	nil
Unsprayed	2·9	47·4	8·0	nil
	n.s.	n.s.	n.s.	

KUMI

		Total fruiting points		
Sprayed	16·6	52·5	62·0	not measured
Unsprayed	9·5	38·1	74·5	
	†	†	n.s.	
		Bolls held (including husks)		
Sprayed	nil	16·3	15·6	14·1
Unsprayed	nil	7·3	6·0	11·3
		‡	‡	n.s.
		Buds and flowers held		
Sprayed	16·6	16·5	nil	20·2
Unsprayed	9·0	7·2	6·5	24·1
	†	†	n.a.[1]	n.s.

SERERE

		Total fruiting points		
Sprayed	24·4	86·9	98·9	not measured
Unsprayed	13·6	53·8	94·4	
	†	†	n.s.	
		Bolls held (including husks)		
Sprayed	nil	20·1	20·1	19·0
Unsprayed	nil	5·4	8·4	13·8
		‡	‡	n.s.
		Buds and flowers held		
Sprayed	23·5	30·7	0·8	12·5
Unsprayed	13·2	13·9	13·4	14·4
	†	†	n.a.[1]	n.s.

TABLE 3 (*cont.*)

ADUKU

	9–10 weeks	*14–15 weeks*	*19–20 weeks*	*25–26 weeks*
		Total fruiting points		
Sprayed	13·7	57·2	68·9	not measured
Unsprayed	8·0	49·3	81·6	
	†	n.s.	n.s.	
		Bolls held (including husks)		
Sprayed	nil	10·7	12·9	10·9
Unsprayed	nil	5·1	11·3	10·3
		•	n.s.	n.s.
		Buds and flowers held		
Sprayed	13·1	33·5	0·9	19·1
Unsprayed	7·7	24·2	11·0	8·4
	†	•	n.s.[1]	•

NGETTA

		Total fruiting points		
Sprayed	9·6	55·1	80·8	not measured
Unsprayed	11·3	53·1	105·2	
	n.s.	n.s.	n.s.	
		Bolls held (including husks)		
Sprayed	nil	8·4	18·3	12·1
Unsprayed	nil	4·3	8·0	11·5
		•	•	n.s.
		Buds and flowers held		
Sprayed	9·3	35·7	4·1	6·0
Unsprayed	10·3	20·0	12·9	15·2
	n.s.	•	•	•

GULU

		Total fruiting points		
Sprayed	3·0	34·5	44·2	not measured
Unsprayed	4·8	40·0	67·2	
	n.s.	n.s.	•	
		Bolls held (including husks)		
Sprayed	nil	2·6	10·3	5·8
Unsprayed	nil	3·2	8·4	10·1
		n.s.	n.s.	†
		Buds and flowers held		
Sprayed	3·0	22·0	4·9	4·3
Unsprayed	4·7	25·9	9·4	6·3
	n.s.	n.s.	•	n.s.

TABLE 4. *Percentage of Fruiting Bodies Shed by Sprayed and Unsprayed Plants by Weeks 14–15*

	Nakabango	*Kumi*	*Serere*	*Aduku*	*Ngetta*	*Gulu*
Sprayed	18	38	42	23	20	17
Unsprayed	22	61	64	41	54	37

The percentage of fruiting bodies that were shed (Table 4) was less for sprayed cotton at all centres at the 14–15-week stage although the absolute numbers varied considerably (see Table 3). The effect of

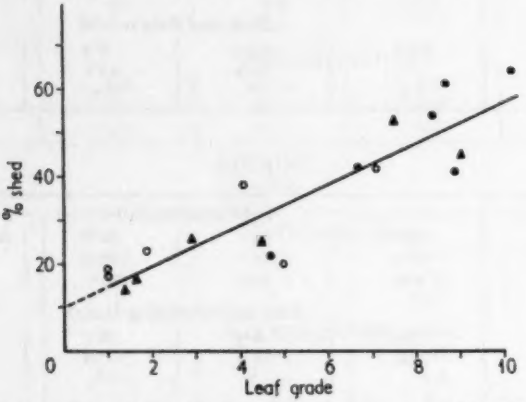

FIG. 2. The relationship between the percentage of fruiting bodies shed and leaf tattering for sprayed (open circles) and unsprayed cotton (closed circles), at 14–15 weeks after planting. Also included (triangles) are values obtained at the same stage in the 1959–60 season.

spraying in reducing both leaf damage and shedding is also shown in Fig. 2, where the percentage of fruiting bodies shed by 14–15 weeks has been plotted against the leaf-tattering grade at this stage, giving a linear relationship ($R^2 = 0{\cdot}78$). Also included in Fig. 2 are values obtained in investigations during 1959–60 at Nakabango, Serere, and Kumi. The good fit of these data to the plotted curve suggests that the relationship may be a general one.

Yield and Boll Setting

At Namulonge, Geering [8], McKinlay and Geering [2], and Coaker [3] reported that spraying treatments resulted in an earlier formation

of the crop. Data in Table 3 agree with this finding, for, except at Nakabango and Gulu, at 14–15 weeks about twice as many bolls were set by sprayed plants as by control ones. This difference was particularly well marked at Serere and Kumi, where rates of growth early in the season were high. At Nakabango and Gulu, where the rate of development was much slower, spraying had no effect in causing an earlier formation of crop and it is significant that at neither of these centres was spraying related to yield increases.

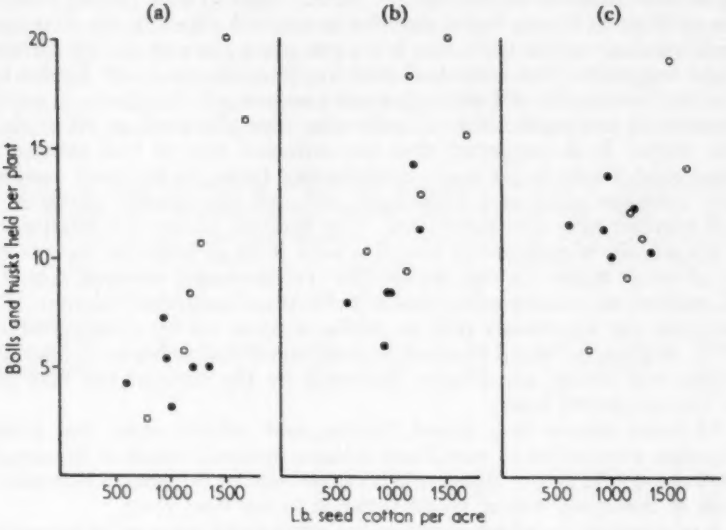

FIG. 3. The relationship between bolls and husks held (*a*) at 14–15 weeks, (*b*) at 19–20 weeks, and (*c*) 25–26 weeks, and final yield of seed cotton. Open circles are data for sprayed trials, closed circles for unsprayed trials. Values of *r* for sprayed and unsprayed trials were 0·92 and 0·02 at 14–15 weeks, 0·49 and 0·31 at 19–20 weeks, and 0·84 and —0·15 at 25–26 weeks.

Yield and bolls held at 14–15, 19–20, and 25–26 weeks after planting, for all trials, are compared in Fig. 3. The correlation coefficient has been calculated for both sprayed and unsprayed trials. For unsprayed cotton there is no statistical correlation between bolls held at any stage and final yield, although from the data for the 19–20-week stage it is clear that in general the more bolls held the greater is the final yield. From Table 3 it will be seen that boll production by unsprayed plants varied considerably both between trials and periods. Thus between the 14–15- and 19–20-week stages unsprayed plants at Nakabango put on nine bolls, whereas those at Kumi showed fewer bolls at the end of the period than at the beginning (6·0 *v.* 7·3). As an indication of the considerable variation within trials some examples of the coefficient

of variation associated with boll number are quoted below:

		Sprayed %	*Unsprayed* %
Nakabango	14–15 weeks	37	42
	19–20 weeks	25	45
Kumi	14–15 weeks	22	40
	19–20 weeks	27	38

In an examination of the Serere, Kumi, Ngetta, and Aduku trials at the 30th week, it was found that the unsprayed plants in the first three trials carried 10 per cent. less bolls per plant than at the 25–26-week stage, suggesting that some boll shedding had occurred. At Aduku boll number was similar at both stages (10·3 and 10·4 bolls/plant). A certain amount of mummification of bolls was also observed at all trials at this stage. It is suggested that the different rate of boll setting for unsprayed plants is the main contributing factor to the poor relationship between yield and bolls held although the greater variation in boll number may also contribute. For sprayed plants this relationship is statistically significant at the $P = 0{\cdot}01$ level at both the 14–15- and 25–26-week stage. In this period (i.e. 14–26 weeks) sprayed cotton at all centres set considerably fewer bolls than unsprayed plants. This supports the hypothesis that an earlier crop is set by sprayed cotton. (P. D. Walton (personal communication) states that at Serere the sprayed cotton was almost completely harvested by the time of the first pick on the unsprayed trial.)

At some centres (e.g. Kumi, Serere, and Aduku) there was a considerable production of new floral buds on sprayed cotton at the 25–26-week stage (Table 3). Because it occurred late in the season this second flush of flowering was of no importance to the final yield.

A mechanism by which spraying can affect yield can now be suggested. Plants at Kumi, Serere, Aduku, and Ngetta, compared with those at Nakabango and Gulu, were well developed and producing large numbers of buds when spraying was begun. Sprayed plants set relatively large numbers of bolls at Kumi and Serere, and rather fewer at Aduku and Ngetta, although at all these centres more bolls were set on sprayed than unsprayed cotton. After spraying was concluded, small numbers of new fruiting bodies were produced by sprayed plants, and much larger numbers were produced by unsprayed plants. At Kumi, Serere, and Ngetta the continued growth of the control plants was not sufficient to bring the yield level up to that of the sprayed cotton. At Aduku the final yields of the two trials were similar. Walton [9] showed that Aduku, over a 12-year period, was the highest-yielding cotton variety trial centre in the areas of Uganda growing S47, whereas Kumi, Serere, and Ngetta yielded considerably lower. It is suggested that the effects of locality and season are such as to favour continued crop production at Aduku, whereas at the other three centres these factors do not allow the continued growth of unsprayed cotton to compensate for the relatively large early crop formed by sprayed plants.

Nakabango is also a high-yielding trial centre. Here, although during the period of spraying development of fruiting points was rapid, it would appear from the leaf-tattering data, and also that on shedding, that insect pest damage was slight. Consequently there was no significant difference in numbers of bolls set at 14–15 weeks for the two trials. Subsequent growth and final yield in both trials was similar. Whether under conditions of more severe early season insect attack continued growth of unsprayed cotton would bring its yield up to that of comparable sprayed material is not known.

The extremely low growth-rate at Gulu is not easy to explain although it may be connected with the cloudy weather associated with heavy rainfall. The rather large depression of yield in the sprayed trial may have been due to soil fertility differences between the two trials. Evidence to support this comes from data on plant height (Table 5), sympodial internode length (Table 6), rate of fruiting-point production

TABLE 5. *Height (cm.) of Main-stem (a), and Number of Main-stem Nodes (b) of Cotton Grown in Various Trials during 1958–9*

	9–10 weeks		*14–15 weeks*		*19–20 weeks*		*25–26 weeks*	
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*
Nakabango								
Sprayed	26	9·7	74	17·9	87	20·5	91	25·0
Unsprayed	25	9·3	86	18·5	105	22·7	103	25·5
	n.s.	n.s.	n.s.	n.s.	*	n.s.	*	n.s.
Kumi								
Sprayed	36	11·1	73	19·1	79	22·6	103	23·9
Unsprayed	26	10·2	61	18·9	98	27·2	134	29·2
	†	n.s.	*	n.s.	*	‡	†	‡
Serere								
Sprayed	49	12·7	108	22·0	117	25·9	127	26·4
Unsprayed	38	11·6	89	19·7	114	26·0	126	25·5
	*	n.s.	†	†	n.s.	n.s.	n.s.	n.s.
Aduku								
Sprayed	33	11·7	101	19·5	114	24·2	136	29·7
Unsprayed	28	10·5	90	19·1	115	25·5	122	26·8
	*	*	*	n.s.	n.s.	n.s.	*	n.s.
Ngetta								
Sprayed	35	10·5	94	19·5	113	24·7	128	28·4
Unsprayed	35	10·3	88	19·5	126	26·9	147	29·3
	n.s.	n.s.	n.s.	n.s.	*	*	*	n.s.
Gulu								
Sprayed	19	9·3	73	17·5	93	21·9	108	28·6
Unsprayed	22	8·9	80	17·1	119	24·4	142	30·1
	*	n.s.	n.s.	n.s.	‡	†	‡	n.s.

* = difference significant at $P = 0.05$. ‡ = difference significant at $P = 0.001$.
† = " " " $P = 0.01$. n.s. = difference not significant.

(Table 3), and main-stem and monopodial-branch internode length (unpublished data) which were all lower for sprayed plants. In addition, the yield variation between plots (Table 1) was high for this trial.

Spraying at Gulu was carried out when there were relatively few fruiting bodies to protect from insect attack. Leaf-tattering records suggest that insect attack was most severe at the 19–20-week stage and it is possible that a slight delay in the timing of the spray application might have given rather different results.

To summarize, it is suggested that yield response to spraying is determined by environmental factors associated with season (e.g. degree of insect pest attack, rainfall) and locality (e.g. soil type and productivity). Where these factors interact against continued crop production by unsprayed plants, by curtailing boll setting, yield may be significantly increased by spraying with insecticide.

TABLE 6. *Node Number (a) and Internode Length (b) of Sympodial Branches Borne Directly on the Main-stem of Cotton Grown in Various Trials during 1958–9*

	14–15 weeks		*19–20 weeks*	
	a	*b*	*a*	*b*
Nakabango				
Sprayed	2·5	4·9	not measured	
Unsprayed	2·5	6·4		
	n.s.	†		
Kumi				
Sprayed	3·1	5·8	3·1	5·3
Unsprayed	2·8	4·8	3·1	4·6
	n.s.	n.s.	n.s.	n.s.
Serere				
Sprayed	3·7	7·4	3·7	7·0
Unsprayed	3·0	5·7	3·3	5·5
	•	†	n.s.	†
Aduku				
Sprayed	3·3	8·2	3·2	7·8
Unsprayed	3·1	6·9	3·5	5·8
	n.s.	•	n.s.	•
Ngetta				
Sprayed	3·2	7·8	3·4	7·2
Unsprayed	3·2	6·9	3·8	5·9
	n.s.	n.s.	n.s.	†
Gulu				
Sprayed	2·5	6·6	2·5	6·3
Unsprayed	2·85	6·9	3·1	6·0
	•	n.s.	•	n.s.

• = difference significant at $P = 0{\cdot}05$. † = difference significant at $P = 0{\cdot}01$.
n.s. = difference not significant.

Other Specific Effects of the Insect Pest Complex

Dale and Coaker [10] reviewed briefly the association between plant height and degree of damage caused by *Lygus vosseleri* Popp., and showed in laboratory studies that there was a mechanism whereby Lygus feeding on, or mechanical damage to, the main-stem growing point could result in a taller plant. In the present work no relation was observed between height and leaf tattering at any stage in the season.

Taylor [11] showed that severe attack by Lygus was correlated with truncation of sympodial branches. This was not observed in the present experiments. Except at Serere, sprayed plants did not show a higher number of nodes per sympodium than control plants at either 14–15 or 19–20 weeks (Table 6). Dale [12] found that continuous removal of all floral buds on BP52 cotton resulted in a significantly larger node number per sympodium for treated plants. In the present study natural fruiting-body loss (shedding) did not cause the same response, possibly because it occurred at a low level compared with the complete removal of all buds in the earlier work.

The tendency for sprayed plants to have longer internodes per sympodium than unsprayed plants is probably connected with the continued growth of the latter plants, producing new sympodial branches with shorter internodes. It has been observed at Namulonge that internodes on branches formed late in the season tend to be considerably shorter than those internodes formed in the early part of the season.

Acknowledgements. The authors wish to thank Mr. P. D. Walton for providing the yield data from the various trials. The interest of Mr. H. L. Manning and Mr. E. O. Pearson, both of whom read the manuscript critically, is gratefully acknowledged.

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(*Received 3 November 1959*)

THE MINERAL COMPOSITION OF FARMYARD MANURE

R. G. HEMINGWAY[1]

(*Agricultural Chemistry Department, The University, Glasgow*)

Summary

Fifty samples of farmyard manure have been examined for nitrogen, phosphorus, potassium, calcium, magnesium, manganese, boron, cobalt, copper, and molybdenum. The average quantities of fertilizer equivalents supplied by 10 tons of manure were 3·5 cwt. of ammonium sulphate, 1·2 cwt. of superphosphate, and 1·0 cwt. of muriate of potash. These values are considerably lower than previous estimates.

The mean content of magnesium in the dry matter was 0·34 per cent. The equivalent of 0·68 cwt. of anhydrous magnesium sulphate is supplied by 10 tons of manure and this is a useful contribution to soil magnesium.

The mean trace-element contents were (in p.p.m.): Mn, 182; B, 23·5; Cu, 19·8; Co, 1·7; Mo, 2·3. Although above-average samples can supply considerable amounts of trace elements, the quantities in general are much below those required for the correction of deficiencies when given as soil applications rather than foliar sprays.

BOYD [1] has recently reviewed the results of a number of field experiments to measure the effects of farmyard manure on the responses of crops to fertilizers. He concluded that the benefits to be derived from the normal use of dung in ordinary rotation farming were entirely chemical and that its influence on the crop by way of improvement in the physical nature of the soil is quite exceptional. The effective value of 10 tons of manure (as opposed to its total composition) was put at 0·3 cwt. N, 0·4 cwt. P_2O_5, and 0·75 cwt. K_2O and it was suggested that other elements, e.g. magnesium, might make some further contribution. Boyd was, however, unable to obtain chemical analyses of the manures used in the majority of the experiments reviewed.

There is, in fact, little available information concerning the mineral composition of farmyard manure. Cooke and Garner [2] have estimated the average composition of fresh manure used in experiments at Rothamsted and Woburn at 0·5 per cent. N, 0·24 per cent. P_2O_5, and 0·5 per cent. K_2O. Very similar figures (0·55 per cent. N, 0·25 per cent. P_2O_5, and 0·55 per cent. K_2O) have been quoted in textbooks for many years: e.g. Smith [3], Reith and Inkson [4] have given the following data for thirteen samples of 'normal cattle dung made with oat or barley straw': H_2O, 72–82 per cent.; total N, 1·3–2·7 per cent.; ash, 13–36 per cent.; P_2O_5, 0·5–1·2 per cent.; K_2O, 1·2–6·3 per cent.; CaO, 1·0–2·1 per cent. Assuming a mean water content of 77 per cent. and an even distribution of samples within these limits, these may be averaged to give a fresh composition of 0·46 per cent. N, 0·19 per cent. P_2O_5, and 0·83 per cent. K_2O. Reith and Inkson have also concluded that the benefits to be derived from dung are in the nutrients supplied, especially the potassium, rather than its physical and biological value.

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[Empire Journ. of Exper. Agric., Vol. 29, No. 113, 1961.]

There appears to be only one set of data for the trace-element composition of farmyard manure. Atkinson *et al.* [5] examined forty-four miscellaneous samples in Canada and found average contents on a dry-matter basis to be (p.p.m.) B, 20·2; Mn, 201·1; Co, 1·04; Cu, 15·6; and Mo, 2·06.

Farmyard manure must still supply an important fraction of the total plant nutrients in British farming and may be the only regular source of trace elements. This is especially so in dairying districts where the low use of fertilizers on grassland is to some extent compensated for by the use of dung. This paper describes the results of analyses of fifty samples of farmyard manure for both major and trace elements.

Farmyard Manure Samples

The fifty samples were originally obtained for investigations (to be published elsewhere) concerning the rate of decomposition of the organic nitrogen and phosphorus components. They have been collected from a wide range of farms in the west of Scotland. The great majority were manure from dairy cows kept in byres but there were a few samples from younger cattle and from pigs. They cannot be truly described as a random sample, but rather as a fortuitous selection. All the samples were partly rotted and in a suitable state for spreading. Most had been stored in open heaps exposed to the weather.

Analytical Determinations

The dry-matter contents ranged from 15·5 to 36·2 per cent. The majority were between 18 and 27 per cent. and the mean was 20·7.

The dried samples were analysed for total nitrogen, phosphorus, potassium, calcium, magnesium, manganese, boron, copper, cobalt, and molybdenum. With the exception of nitrogen, the determinations were made after ashing at 500° C. using standard methods of analysis in current use for plant material.

Results

The data for the analyses of the fifty samples are represented diagramatically in Fig. 1. The mean contents and their equivalents in terms of fertilizer salts in 10 tons of manure containing 80 per cent. of water are given in Table 1.

Nitrogen

There was a wide range of values from 0·52 to 3·47 per cent. N. The mean equivalent value of 3·46 cwt. of ammonium sulphate compares with Cooke and Garner's estimate of 5 cwt. Indeed, only some 15 per cent. of the samples reached this level and 5 per cent. contained less than the equivalent of 1 cwt. of ammonium sulphate for a 10-ton dressing. As it would appear to be unlikely that more than perhaps 30 per cent. of the total nitrogen in dung is utilized in the first year, it is not surprising that Crowther and Yates [6] concluded that nitrogenous fertilizer applications should not be reduced when farmyard manure was also used.

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TABLE 1. *Mean Composition of Fifty samples of Farmyard Manure*

Element	*Content in dry matter*	*Supplied by 10 tons F.Y.M. (20% dry matter)*
	%	*cwt.*
N	1·73	3·46 $(NH_4)_2SO_4$
P	0·24	1·20 Superphosphate (18%P_2O_5)
K	1·29	1·03 Muriate of potash
Ca	0·74	0·74 $CaCO_3$
Mg	0·34	0·68 $MgSO_4$
	p.p.m.	*oz.*
Mn	182	52·3 $MnSO_4.4H_2O$
B	23·5	14·7 $Na_2B_4O_7.10H_2O$
Cu	19·8	5·6 $CuSO_4.5H_2O$
Co	1·66	0·56 $CoSO_4.7H_2O$
Mo	2·32	0·46 $Na_2MoO_4.2H_2O$

Phosphorus

The mean phosphorus content of 0·24 per cent. P was equivalent to 1·2 cwt. of superphosphate (18 per cent. P_2O_5) from a 10-ton dressing. Previous estimates of 0·25 per cent. P_2O_5 on a fresh-matter basis give a superphosphate value of 2·75 cwt., whilst the data of Reith and Inkson indicate a mean application of 2·1 cwt.

These results therefore indicate that many samples of manure are much lower in total phosphorus than is currently supposed.

Potassium

Only two samples had over 3·0 per cent. K in the dry matter and some 39 per cent. had less than 1·0 per cent. K. The mean dry matter content was 1·29 per cent. K, i.e. 0·25 per cent. K in the fresh material. This compares with quoted data of 0·5 K_2O [2, 3] and 0·8 per cent. K_2O [4]. In terms of muriate of potash the mean dressing would be 1·03 cwt. per 10 tons of manure.

These samples therefore reveal much lower potassium levels than would be expected. It would appear to be of the greatest importance that this be taken into account in formulating manurial policy and the possibility of great variability in potassium contents be appreciated in interpreting field experiments comparing fertilizers and farmyard manure.

Calcium

Only rarely did the calcium content rise above 1·0 per cent. The mean value of 0·74 per cent. Ca indicates a contribution of 0·74 cwt. of calcium carbonate from the standard dressing. This can have no significant influence on the calcium status of either soils or plants.

Magnesium

The variation in magnesium content was from 0·14 to 0·58 per cent., the mean value being 0·34 per cent. Mg. This is equivalent to 0·68 cwt.

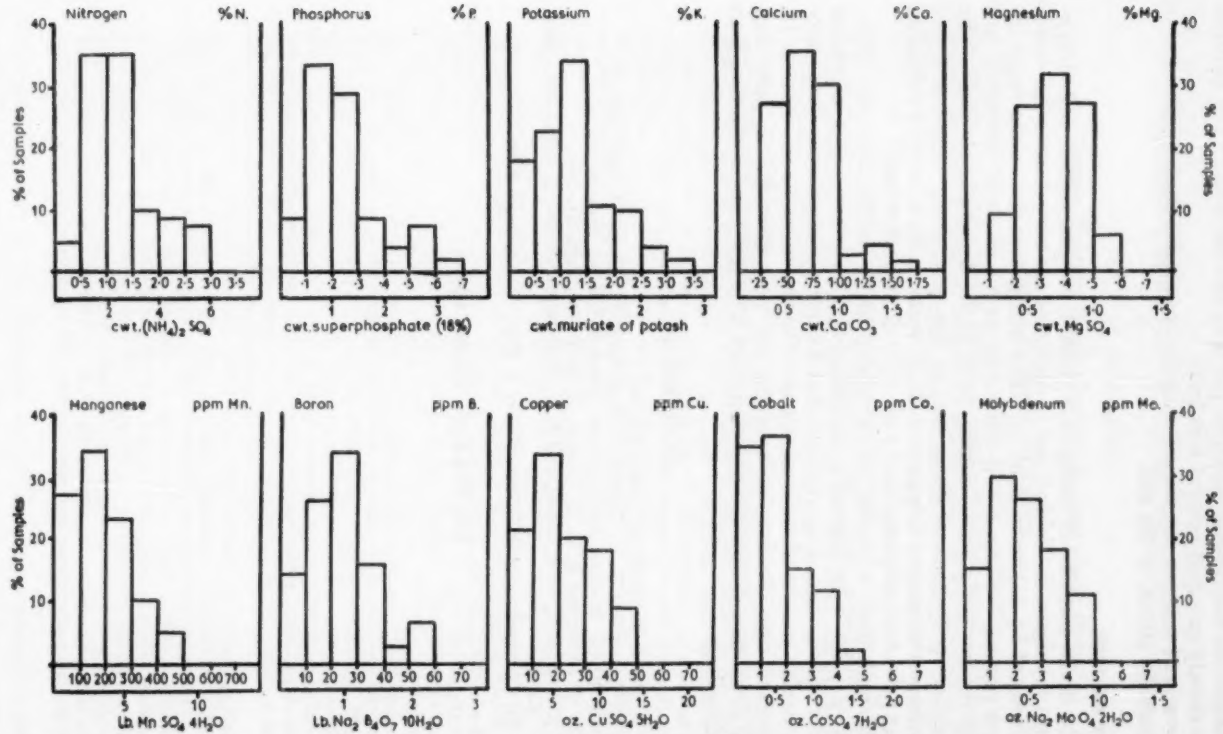

FIG. 1. Analysis of fifty samples of farmyard manure. In each graph, on the axis of abscissae, the upper scale is for dry matter composition (per cent. or p.p.m.) and the lower scale is for equivalent fertilizer salts (cwt., lb., or oz.) in 10 tons of f.y.m.

of anhydrous magnesium sulphate per acre and the majority of samples were closely grouped around this level.

Farmyard manure can therefore make reasonable contribution to the magnesium status of the soil.

Trace elements

The mean contents of manganese, boron, copper, cobalt, and molybdenum are shown in Table 1 and in each case are very close to the values put forward by Atkinson *et al.* [5]. For manganese the values range up to 500 p.p.m., for boron and copper to 50 p.p.m., and for cobalt and molybdenum to 5 p.p.m. Taking these as the highest levels likely to be encountered, 10 tons of dung can, at the maximum, supply 9 lb. of anhydrous manganese sulphate, 2 lb. of borax, 1 lb. of copper sulphate, 1·7 oz. of cobalt sulphate, and 1 oz. of sodium molybdate.

Although these amounts are in general much smaller than the quantities of pure salts normally recommended as preventative measures against deficiencies, it is apparent that farmyard manure may frequently be a useful source of trace elements. On the other hand, it must be recognized that the average contents are very considerably less than these amounts and that spray applications are usually more effective than soil dressings.

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(*Received* 26 *October* 1959)

FARMING ORGANIZATION IN CENTRAL IRAQ

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Summary and Conclusions

The most important factor in the administration of the farming system, brought out by these detailed studies, is the considerable degree of discipline and co-operation required on the part of the cultivators and the very considerable obstacles which such a system must present to any attempt to improve agricultural practices or to alter the system of farming or cropping rotation. The system of communal strip farming does not lend itself to any great degree of individual choice and any change must be adopted by the whole group or not at all. The success of the cropping system depends upon the willing compliance of each and every cultivator in the decisions of the landlord or his agent, and unless each one co-operates the success of the whole cropping may be endangered.

The decisions of the landlord revolve around three main subjects. First, there is the group of decisions concerning which fields are to be cultivated in any one year. This is governed by the custom of the rotation of crop and fallow in alternate years in the case of winter crops and by the availability of water in the case of summer crops. It is also governed by the need to conserve water and rotate the canals in use as far as possible. This gives rise to the necessity of rotating the cropping in large blocks all watered from one or a group of canals. Second, there is the group of decisions concerning which crops are to be grown and in which fields. These decisions demand a considerable degree of obedience on the part of the individual, although allowing him some freedom as to his exact choice of crops. The date of the first ploughing and of seed broadcasting is generally agreed upon communally and unless everyone ploughs and sows together the irrigation routine will become disorganized. Individuals cannot sow earlier than the chosen date, although they may sow later. This explains why, although the fields in the diagrams are farmed by many farmers, they are almost all planted to the same crop. The selection of which crops to grow is determined in the first place by the need to produce enough wheat and barley to feed the family and livestock and only secondly by the needs of the market. The third group of decisions concerns how big an area, and of which crops, shall be allocated to each farmer. This depends mainly on the size of the farm and the number of farmers. If there is a shortage of cultivators in relation to the land available the upper limit to the area cropped will remain the cultivator's choice. But if the area is small in relation to the number of cultivators it is apportioned out fairly between families according to their capacity to cultivate it successfully (so as to achieve the maximum output from the area) and taking into consideration the family needs of each cultivator (so that no cultivator shall have such a small area that he cannot support his dependants from it).

The striking similarity between this system and that in force in England until the end of the eighteenth century does not need emphasis. The same stultifying effect upon innovation and the same hindrance to higher productivity as have been remarked upon as the main features of that system are true of this system as it existed in Iraq. The picture in Iraq has now altered with the introduction of a programme of land reform and the situation as described in this paper is in process of upheaval; nevertheless a description of the organization of agriculture as it existed prior to land reform, and particularly of the changes that were occurring on the larger holdings, has perhaps more than merely historical interest.

THE rapid increase in the revenues which Iraq has obtained from the expansion of oil production in recent years has enabled her to set aside

[Empire Journ. of Exper. Agric., Vol. 29, No. 113, 1961.]

large sums for national development. This expenditure has been administered through a semi-autonomous Development Board, now abolished. Among the major schemes initiated by the Board have been those concerned with controlling the destructive floods of the River Tigris and its tributaries. Three major flood-control schemes have so

FIG. 1. Map of part of the river system of Iraq.

far been completed or partly completed. One of these has been the building of a dam at Derbendi-Khan on the headwaters of the Diyala river, a tributary of the Tigris, arising in Iran and flowing in a south-westerly direction to join the Tigris a few miles downstream from Baghdad (see Fig. 1). Apart from the benefits of flood control, one of the great advantages of this dam will be the considerable increase in the supply of irrigation water which will become available upon its completion during 1961 or 1962.

Since the area of potentially irrigable land is greatly in excess of the area that could be irrigated by the additional waters that would become

available, and since little was known about the quality of the available land, the Iraq Development Board appointed a firm of consultants (Sir Murdoch MacDonald and Partners) to advise on the best use of the Derbendi-Khan dam waters and on the best methods of developing the lands of the Diyala river basin together with those of that part of the Tigris river basin from the confluence with the Diyala river downstream as far as Kut. The soil and agricultural aspects of this study were investigated by Hunting Technical Services Limited.

The results presented in this paper concern some of the agricultural aspects of this study, with particular reference to the economic position of the individual farmer and to the present organization structure of farming.

It should be mentioned that the situation as described in the next section on the general setting, and in the section on the individual villages, no longer exists. The description refers to the period up to the middle of the summer of 1958. With the introduction of the Agrarian Reform Law in July of that year the whole of the organization of agriculture in Iraq had undergone a major change. The main provisions of the law, that holdings in excess of 620 acres should be distributed to the landless peasants who cultivated them, in units of 36 acres, have reversed the direction of change in which agriculture was previously moving.

The General Setting

The project lands, apart from the mountainous area to the north, can be divided into two main regions: the Diyala basin, stretching for some 150 miles from Derbendi-Khan to Baghdad and covering 1·5 million acres of potentially irrigable land; and the middle reaches of the Tigris basin from Baghdad to Kut, some 100 miles in length and covering another 1·4 million acres of potentially irrigable land; a total area of almost 3 million acres. A land classification survey of the region indicated that almost two-thirds of this whole area was suitable for intensive irrigation development. The area irrigated at present covers only some 1·9 million acres out of this total of 3 million acres.

The climate of the region is semi-arid, characterized by very long, hot, dry summers, with maximum temperatures exceeding 100° F. from June to September, and by cool moist winters. Rainfall is confined to the period from October to May, occurring mostly between November and March. In the north of the region the rainfall is sufficient, in some five or six years out of ten, to grow a moderate crop of winter cereal, the average rainfall at Khanaqin being just over 13 in. Rainfall drops off farther south, averaging less than 6 in. a year at Baghdad and slightly less at Kut. Hence over most of the area agriculture is entirely dependent upon irrigation.

Water-supplies in the rivers are unevenly distributed throughout the year, and whilst it is climatically possible to grow two crops a year over the whole area the limitation of water-supplies severely restricts the area cropped during the summer. River flows in the Diyala river are

very low from July to October, rise gradually during the winter, and reach a peak during April when the volume of water in the river is more than ten times as great as in August and September.

The main winter crops grown are wheat and barley, which are planted between October and December and harvested from late April to the end of June. They thus coincide with the period of maximum water availability. The summer crops, however, coincide with the period of water scarcity. Cotton, planted in April and ripening from August to November, is the principal summer crop, and must be planted on land which has been fallow during the winter. The area of summer vegetables, which may be planted as early as January, has increased considerably in recent years as the size of the Baghdad market has grown, and they are now the second most important summer crop. The other important summer crop is rice, which can be planted after the winter crop has been harvested. Some perennial crops are grown, mainly orchards, and though these are generally limited by the availability of assured summer water-supplies, they assume considerable importance in some areas.

The land is farmed under a simple fallow rotation, a season of winter cereal being followed by a season of winter fallow, the land returning to cereal again in the third year. The area under winter crops never exceeds 50 per cent. of the irrigated area and is normally about 40–44 per cent. The area under summer crops, which is determined by the availability of irrigation water, varies from about 3 per cent. of the irrigated area in the Diyala basin, where irrigation is dependent on gravity-flow canals, up to 6 per cent. along the Tigris, where the water is pumped.

Although this fallow system appears extremely wasteful of land and condemns the whole area to extremely low productivity, under the prevailing conditions it is a logical system. With water-supplies scarce and labour limited, but with ample areas of land, the system makes fair use of the available resources. In addition, if it were not for the fallow system the area could not have continued in production at all. As it is, the water table is at extremely high, barely tolerable, levels; parts of the area suffer from grossly saline soils and cannot be used; and the general level of soil fertility is extremely low. The fallow system gives the land a chance to dry out so that when it is next irrigated the water can move freely downwards, taking with it accumulations of salt in the upper soil layers; and the weeds which grow on the fallow, being mainly leguminous, provide the only alternative to complete dependence on non-symbiotic fixation of nitrogen to maintain the nitrogen supplies of the soil.

Not only is the intensity of the farming system thus extremely low, and condemned to remain so until additional water-supplies and a drainage system can remove the limitations to an intensified agriculture, but the yield per unit area is also low. For instance, average wheat and barley yields in the area are only some 600 and 825 lb. per acre respectively, and cotton yields are only about half those obtained in Egypt and the Sudan. Livestock yields are equally low, milk yields per cow being

about 150 gallons per lactation at most. The reasons for these low yields are many. On the one hand natural conditions are adverse, though not beyond hope of remedy; climatic conditions are extreme; soil fertility is low and is further limited by salinization; and natural drainage is poor. On the other hand, cultural practices are not conducive to high yields; land-preparation methods have not changed since Babylonian days, little care is given to the growing crop, poor quality dirty seed is sown at seeding rates too low to give a reasonable plant population, and so on. It lies within the power of the individual farmer to remedy most of these impediments to higher production if he is given the incentive and the knowledge of how to do so.

Given such a combination of factors, together with the primitive methods employed, which limit the area that can be cultivated by any one person, it is perhaps understandable that the output per person employed is extremely low. There is yet another factor, however, which influences the rural standard of living: the prevailing system of share-cropping land tenure. Most of the land is in the hands of large landowners who lease it out, together with requisite water for cultivation, to tenants who cultivate the land, in return for a share of the crops. The actual share of the crop demanded by the landowner varies considerably from one part of the area to another, and from crop to crop. The customary division is for owner and tenant to share the crop half and half; if the water is supplied from a gravity-flow canal maintained by the government the landowner may only retain two-fifths; if the owner provides the seed he may retain as much as two-thirds; if in addition he cultivates the land for the tenants he may take a still larger share. In general it is rare for a tenant to be left with more than half what he produces and in many cases he may well receive considerably less.

Detailed Village Studies

During the course of the investigations into the soil and agricultural conditions of the area, some detailed studies were conducted of a few individual villages in order to try and assess the area of land being cropped by individual tenant cultivators, the probable level of output per worker, and the proportion of output he retained, and in order to investigate the detailed organization of agriculture at the village level. The village was chosen as the unit for investigation since this is the nearest equivalent to a normal 'farm' in the west-European sense. Where the land is owned in small- or medium-sized holdings of from 100 to 1,000 acres the tenants generally live in a single village and are organized as one body. Where ownership is in larger units, and one man may own as much as 100,000 acres, the holdings will be subdivided into blocks, each block being farmed by the inhabitants of a single village, organized by an agent of the owner, resident in the village.

Only six villages were so investigated and with considerable variation in the amount of detail recorded. The organization of three of these is examined in this paper.

Village A

This village lies about 40 miles north of Baghdad in the Baquba district, and all irrigation water derives from gravity-flow canals. The land belongs to one Sheikh Mohammed, whose grandfather was a fairly large landowner in this district, but as the land has been subdivided over two generations, Mohammed now owns only about 180 acres. He farms this area with his two younger brothers and their families, and his son. There is thus no share-cropping as such but the organization is fairly similar to that followed on other holdings where there are tenants.

The normal fallow system of farming is practised and in Fig. 2 the rotation of the land between different winter crops is illustrated; the summer crops, being in very small blocks, are not shown, for the sake of simplicity. This figure gives a good picture of the way the fallow system functions. It can be seen how land which is cropped one winter is fallowed the next and cropped again the year after. There are small variations within this pattern, some areas being uncropped for two years running, often because they have been used for cotton. It is not possible to deduce from this diagram whether the same crops are grown in the same position in alternate years; on the one hand the northerly field has been under wheat twice in four years; on the other the central area was first under barley and later under linseed. The area which is planted to wheat and barley is determined almost entirely by the subsistence needs of the village, and is based on their estimates of their annual requirements; any remaining area in the winter is planted to linseed, as the most profitable alternative cash crop.

The cropping distribution for the 1957–8 crops was:

Winter crops 1957–8	*Acres*	Summer crops 1958	*Acres*
Wheat	14	Cotton	7
Barley	25	Other crops	2
Linseed	19		
Other crops	1		
Winter fallow	73	Fallow	123
Total	132	*Total*	132
		Orchards	1
		Unused land, waste, &c.	54
		Total gross area	187

The comparatively small area of summer crops is obvious from this table as well as the surprisingly high proportion of unused land within the holding; mainly saline, high land, or land in depressions subject to waterlogging.

The distribution of land among the farmers, even though they are all relations, follows the same pattern as in other holdings of the area, and was studied in some detail. Each field, as can be seen from Fig. 2, is devoted to a particular crop, and subdivided among the cultivators, into strips. Sometimes each cultivator merely has one strip in each

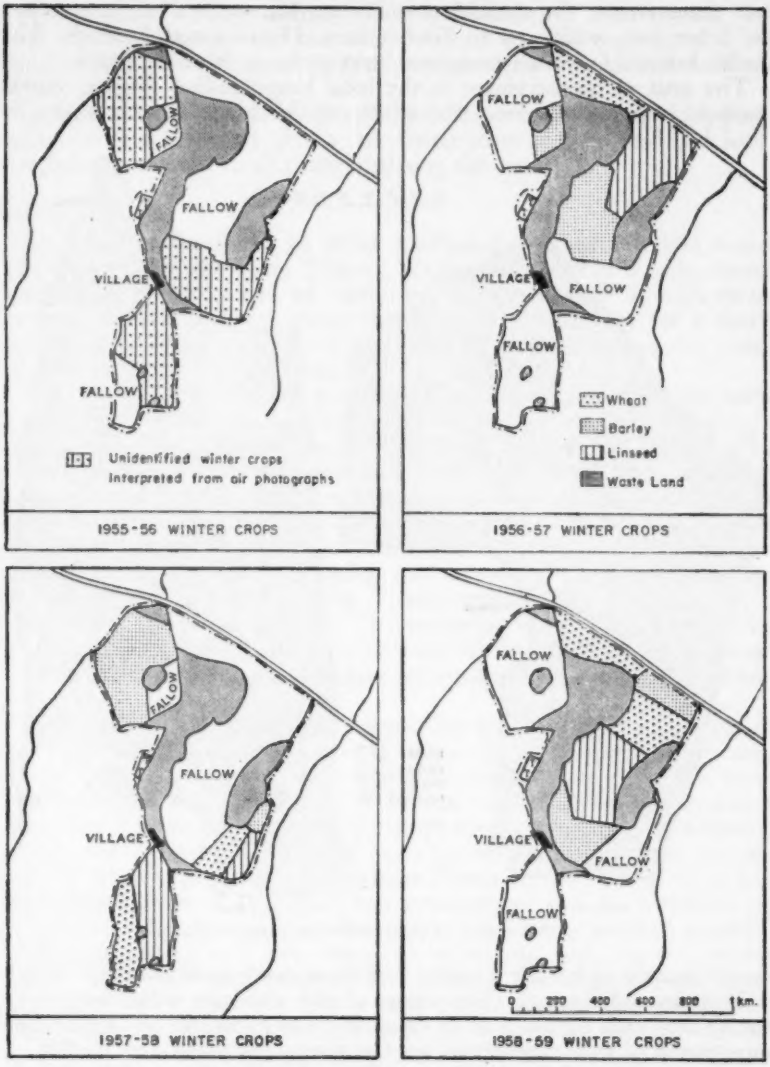

FIG. 2. Village in the Baquba district showing fallow system.

field; sometimes the field is split up into blocks and each cultivator has one strip in each block. This system has striking similarities to the old English open-field system. In this particular village this system appears to have reached an extreme situation. The fields are divided up into blocks of approximately 1½ acres in size and each block is subdivided

into three strips; the sheikh's son Hassan has one, rather larger than the other two, which go to his brothers, Hussein and Karmel. The sheikh himself farms an occasional strip at the ends of the fields.

The unit of measurement is the local long-handled digging shovel (*mishah*) some 6–8 ft. long, the width of the block corresponding to

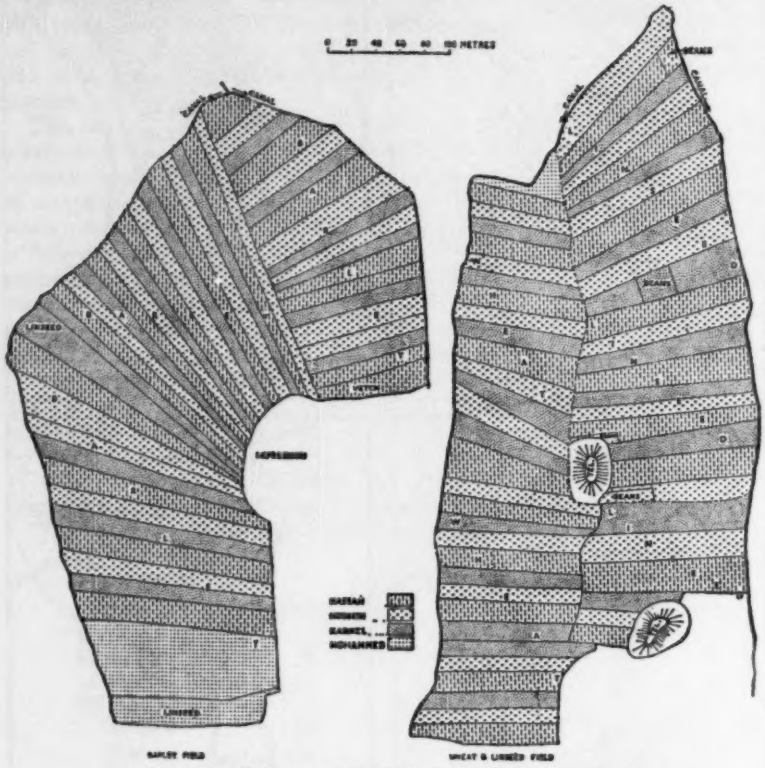

FIG. 3. Allocation of strips between share-croppers.

approximately 20 handle lengths, 8 of these going to Hassan and 6 each to Hussein and Karmel. The object of this elaborate subdivision is to ensure that each person gets an equal share of good and bad land. The appearance of this subdivision on the ground is illustrated in Fig. 3, representing the wheat, barley, and linseed fields of 1957–8 in Fig. 2. In the wheat/linseed field there are 31 strips of wheat and 27 strips of linseed averaging less than half an acre in size. In the barley field there are 48 strips averaging just over half an acre. It will be noticed that a rigid uniformity of cropping is not enforced in either case and small areas of different crops occur within the larger block of the main crop, e.g. the large strip of linseed in the middle of the barley field; it

was sown there because Karmel had some seed over after sowing the main linseed area and did not want to keep it until next year. The area farmed per worker is 20 acres of winter crop and 3 acres of summer crop.

In spite of the intensely complicated appearance of this cropping pattern it does evidently give a fair distribution of good and bad land in equal proportions to all those cropping the land.

Village B

This village lies about 90 miles south-east of Baghdad and some 6 miles south of the River Tigris. Water derives from a large canal direct from the river and all water is pumped, though at high river levels in the spring water enters the canal by gravity flow for a short period. A small pump is also required to lift the water from the main canal on to the village land area.

The whole of the area for many miles around is owned by one very large landowner, but the area farmed by this village has been leased out for many years to the present sheikh who lives in the village. He organizes all agricultural production, determines what crops shall be grown in which fields, allocates the land to the cultivators, owns the water pump and pays for its maintenance, taking in return a half share of all crops grown. He had eight families working for him in the village in 1958, with ten share-cropping cultivators. This is considerably fewer than some years previously. There were twelve families in 1955, for instance, and nine in 1957. The migration of the rural population to urban areas and the consequent decrease in the number of agricultural workers is one of the major problems facing the agricultural organization of this area.

Fig. 4 presents the cropping pattern for the whole farm for 1957–8 and 1958–9, including the summer crops, as well as an enlargement of the 1957 summer and 1957–8 winter crop area showing the strip distribution between cultivators. The total area of the holding is about 660 acres. For the sake of clarity the crops shown as the 1957–8 cropping pattern are the summer crops of 1957 (green gram, *Phaseolus aureus*) and the winter crops of 1957–8; those shown as the 1958–9 crops are the summer crops of 1958 (rice and green gram) and the winter crops of 1958–9. An area of cotton that should have been the 1958 summer crop is not shown as it was destroyed by locusts, and rice was grown instead. The unusual feature of this figure is the comparatively large area of beans in 1957–8. These were grown during that year in an attempt to find a more profitable cash crop than the normal cereals. As already mentioned the area of wheat and barley planted is basically determined by the subsistence needs of the village and any surplus land available can then be planted to whichever alternative crop is most profitable. In this particular case the sheikh thought that beans would grow well.

Apart from this the rotation follows the expected course of the fallow system. The 1956–7 winter crops (not shown) were on approximately the same areas as those of 1958–9. The 1957 green gram crop followed

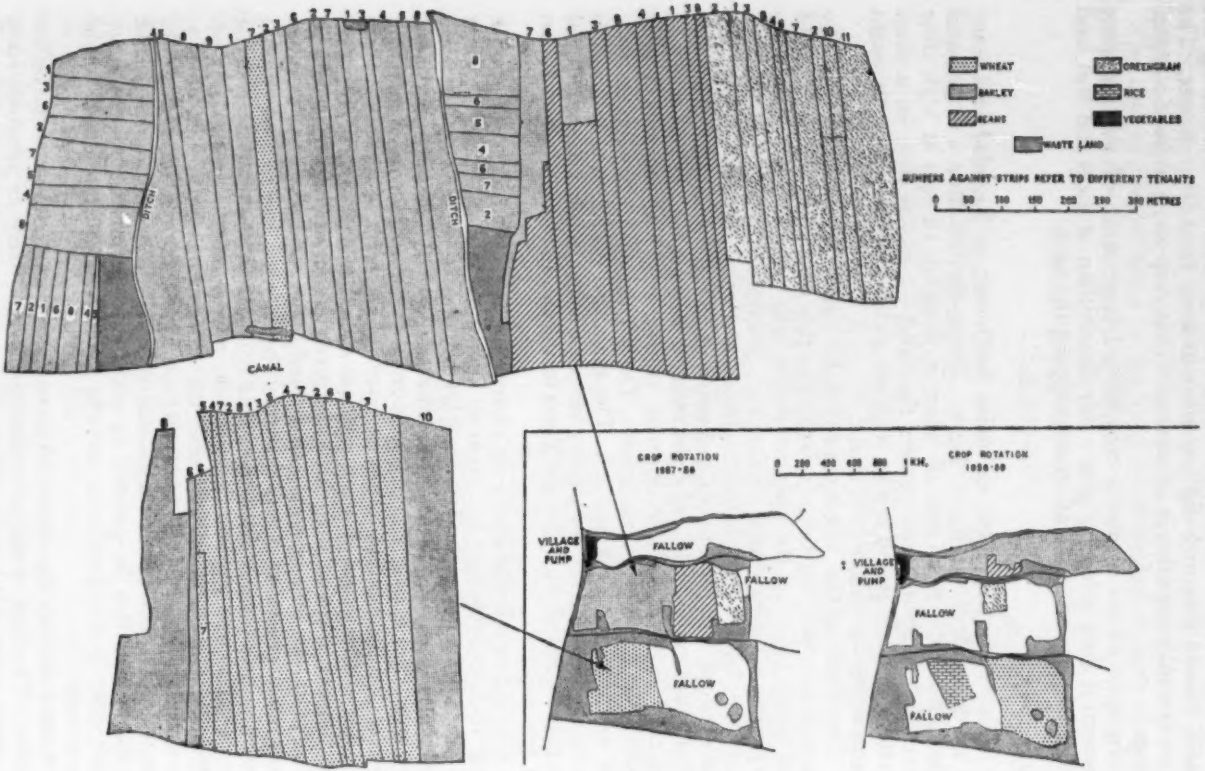

FIG. 4. Allocation of strips between tenants.

on after these. The land which was fallow in 1956–7 was cropped in 1957–8 and again returned to fallow in the following winter. Part of it was used for the 1958 summer crops, green gram following beans and rice following wheat; and this area was again to be used for winter crops during the 1959–60 season. The two maps of the farm in separate years depict this succession of crops.

The fields, which are shown separately according to their division between the share-cropping cultivators, correspond to the 1957–8 map. These show in the same way as Fig. 3 the subdivision into strips. The size of the area allotted to each family depends on two main factors, primarily the working capacity of the family, secondarily the needs of the family. The number of strips into which the total area is divided and their size depends upon the importance put upon ensuring a fair distribution of good and bad land between families. In Village A the average size of strip was about half an acre and each cultivator had many strips in each field. On the other hand, in another village studied, each farmer had only one strip in each field and subdivided his own strip according to the crops that he wanted to grow, the size of the strip depending on the size of the field and averaging about 12 acres. In Village B the subdivision comes part way between these cases, and the average size of strip is just over 3 acres. The method of land division is similar to that followed in Village A. The whole area to be cropped is first divided into fields which are of roughly uniform soil type and hence of similar yielding capacity within themselves. Each share-cropper is then allocated one strip within each field, though if the field is large it may be subdivided and each person given one strip in each half. The objective of achieving a fair distribution of good and bad land between cultivators is thus achieved more simply than in Village A. There is also more uniformity of cropping, most of the strips within a field usually being planted to the same crop.

It will be noticed from the diagram showing the allocation of strips between tenants, that nos. 1 to 8 are represented equally throughout all the winter crops: these are the eight cultivator families; that nos. 9 and 10 have only three strips: these are the sheikh's sons; that no. 11 is only found in the green gram, and no. 5 is not found in the green gram because no. 11 left at the end of the 1957 summer and was replaced by no. 5.

The cropping distribution for the 1957–8 year is shown below:

Winter crops 1957–8	*Acres*	Summer crops 1958	*Acres*
Wheat	113	Green gram	7
Barley	45	Rice	19
Beans	32	Vegetables	1
Winter fallow	234	Summer fallow	397
Total	424	*Total*	424
		Unused land, waste, ditches, &c.	238
		Total gross area	662

The proportions of winter crop to total area and of summer crop to winter crop are similar to those of Village A. The winter crop area is slightly under half the cultivated area. The proportion of the gross area which is unused or waste land, at over one-third, is even higher than in Village A. The area farmed per worker is fairly similar to Village A, with 19 acres of winter crop and 3½ acres of summer crop.

These two villages are typical of the small traditional methods of organization found throughout so much of the irrigated areas of central Iraq; an organization that has developed out of the old tribal structure. Under this the land was divided into areas exclusive to members of individual tribes. The cultivated land was held by the tribal chief and subchiefs who employed the peasants and organized the cultivation. The peasants did not hold land nor were they attached to the soil. With the weakening of tribal ties and the progress of land settlement the tribal chief became a landlord and the tribal members his tenants. Villages A and B represent the typical position which agricultural organization reached before recent changes towards commercial farming made themselves felt. The extent of the change from this system to one adapted to modern requirements of commercial farming can be seen in Village C.

Village C

This village lies very close to Village B, but adjoins the River Tigris and stretches away from it in a wide arc. All water is pumped from the river. The gross area of the holding is 3,400 acres, all in one ownership. The owner lives in a great house on the river but the cultivators in a village about 2 miles away.

Recent years have seen a considerable change in the organization of the holding. Ten or fifteen years ago it would not have differed appreciably from either of the other villages, but between 1950 and 1958 the number of cultivators dropped from 100 to 21. This was partly attributable to disastrous floods in 1954 but also in part it reflects a similar change in other areas; increasing opportunities of urban employment have been drawing the rural population off the land and into the towns, all over the country. The owner has reacted to this depopulation in the only way open to him, by mechanizing his production. He has not responded by lowering the proportion of the crop which he takes from his cultivators, a reaction which might equally well have been expected, because these proportions are more a matter of local custom than individual convenience, and not readily changeable by a single owner in isolation.

Part of the area is run as a mechanized farm by the owner. The sequence of operations on the winter crops is to plough by tractor, broadcast the seed by hand, and cover the seed with disk harrows. The crop is harvested by combine harvester. Labour requirements are thus very low, merely broadcasting the seed, about three or four irrigations and occasional supervision, and the owner employs monthly-paid labour from the village at about £6 per month. The remainder of the land is divided up between the share-cropping cultivators in a similar fashion

to the other villages. The landowner ploughs this for them by tractor gratis. The seed, provided by the owner but reclaimed by him at harvest out of the cultivator's share, is broadcast on the ploughed land and may be covered either by ploughing by horse and wooden plough or else disk-harrowed by tractor, for which he charges about 10*s*. per acre. The cultivators prefer to cover the seed with a horse plough as it is cheaper. Harvest is sometimes by combine harvester, but the cultivators prefer to cut by hand as they are charged 15 per cent. of their share of the crop for the use of the combine. The procedure for the cultivation of the summer crops is similar.

The crop rotation followed is identical with that described in connexion with the other villages, and it is depicted in Fig. 5. This shows how the holding is divided into two approximately equal parts by the main road and these are taken as the basic divisions of the fallow system. The part to the north is cropped in one year, that to the south the next year. That to the north was cropped in 1956–7 and again in 1958–9, that to the south in 1957–8.

The 1957–8 cropping distribution is given below:

WINTER CROPS	*Acres*	SUMMER CROPS	*Acres*
Wheat	780	Rice	162
Barley	296	Cotton	56
Linseed	74		
Winter fallow	1,195	Summer fallow	2,127
Total	2,345	*Total*	2,345
		Orchards	46
		Unused, waste, ditches	1,009
		Total gross area	3,400

The proportions of winter crops, summer crops, and waste area are again approximately similar to those found in the other villages, but the area of winter crop farmed per worker is more than twice as large, 57½ acres of winter crop as against 20 acres, entirely as a result of mechanization. The area of summer crop is similar since these cultivators only crop the cotton. The rice is cultivated by a completely different set of share-croppers whom the owner has recently settled on his holding. They have migrated from the poorer rice-growing areas farther south and cultivate no winter crops at all.

This holding illustrates the changes that were occurring in Iraq agriculture prior to land reform: (1) the area farmed per worker was increasing through the mechanization of production, itself the response to rural migration; (2) the beginnings of an alternative to the share-cropping system were emerging, the landowner farming part of his holding on his own account and employing wage-paid labour instead of share-croppers; (3) some specialization of production was occurring, instanced in this case by the group of cultivators growing only rice, indicating another step along the road from subsistence to commercial farming. With the break-up of the large holdings and the distribution

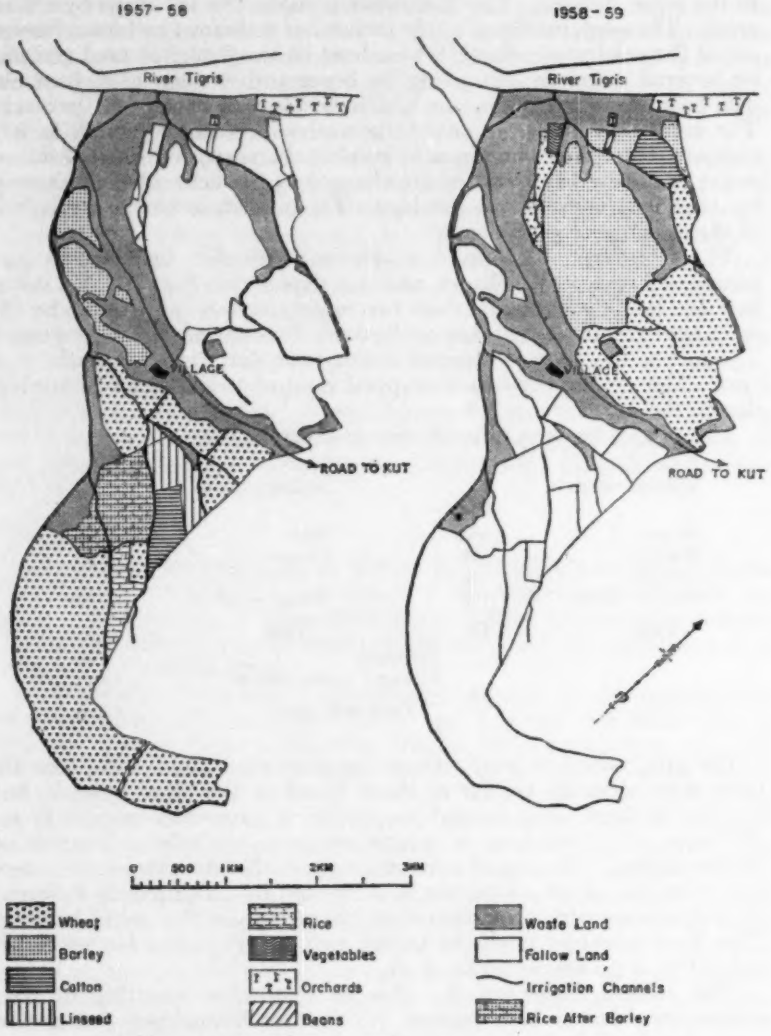

FIG. 5. Middle Tigris, Village C, cropping rotation.

of land in holdings of 36 acres to the landless cultivators the direction of change will alter.

Livestock

No account of livestock has been taken in this description of the village organization. Most of the cultivator families own their own

livestock and give no share of the produce to their landlord. Livestock husbandry is not integrated into the farming system and stock exists on such waste foods and rough grazings as are available.

For ploughing and transport the main reliance is placed on the horse and generally at least half the families in a village will own one horse; the possession of more indicates considerable wealth. Ploughing is also performed by cattle and donkeys.

The main reason for keeping livestock in the villages, apart from ploughing purposes, is for the production of dairy produce, particularly clarified butter and butter milk, and the main animal kept in these villages is the cow. The production of meat by the ordinary cultivator is generally of secondary importance, since he rarely consumes it himself, and although, in Iraq as a whole, sheep and goats are kept on a large scale for producing milk and butter, wool and meat, they are not often found in this project area in the ownership of share-cropping cultivators. On the other hand all the resident sheikhs in the villages studied maintained quite large flocks of sheep, up to 200 ewes in one case. Only in one village did many of the cultivators keep sheep.

Almost every household in each village had one or two cows for their own use. Some part of the produce is probably sold, as it fetches a good price and is readily sold in small lots, but on the whole livestock are kept mainly for providing the family with food. In most of the villages, animal output is relatively unimportant in terms of value compared with crop output, but in terms of nutrition the produce helps to balance a diet which is otherwise extremely high in carbohydrates.

Financial Results

One of the main intentions of these village studies was the determination of the output per worker engaged in agriculture and of the standard of living in the rural areas. This paper concentrates on the organizational aspects of agriculture but brief mention should be made of the other results obtained. A study of such a small sample can obviously not be taken as statistically valid but a few useful generalizations can be made.

The value of the gross output per worker was estimated to fall within the range £100–180. In the particular villages studied neither mechanization nor the existence of a landlord appeared to increase the value of the output of the winter crops per acre, and so, although mechanization greatly increased the area of these per worker, it did not greatly increase the value of their output per worker; in fact if the extra costs of mechanization are deducted, the output per worker is reduced. But the value of summer crops per worker is higher as a result of mechanization, and as a result of this the value of gross output per worker is higher in the more highly mechanized holdings. Apart from this the causes of variation were so various that no one particular cause is dominant.

The value of crops and livestock produce available to the worker after deducting the share of the crop given to the landowner ranges between £63 and £98. The higher figure is for Village A where the landowner is one of the village families and no crop share has to be deducted. It is

probable that a truer figure for the average income per cultivator is therefore around £70–75 of which about one-half comes from the winter crops, one-third from livestock, and one-sixth from the summer crops. The minimum value of output required for subsistence, that is to say the amount consumed in the family, is between £35 and £45, leaving the approximate cash income available to the cultivators at about £30 a year. The income per average family would be about 20–25 per cent. greater since there is sometimes more than one cultivator per family.

(*Received 29 August 1959*)

FERTILIZER PRACTICE IN ENGLAND AND WALES
I. GENERAL FEATURES OF FERTILIZER CONSUMPTION 1956–7

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Summary

Fertilizer practice surveys were made in thirty-five districts in England and Wales in 1957. This first part of the paper gives estimates of the average consumption of N, P, and K within three groups of districts: (1) arable districts, (2) lowland grassland districts, and (3) English upland districts and Wales. Changes in consumption since 1953 are examined, using the results of previous surveys.

The arable farming districts used between two and three times as much N and K per acre as the lowland grassland districts and four to five times as much as in the upland districts; much the same differences were found for water-soluble P, but not for total P, since more basic slag and rock phosphate were used in the grassland districts. In all districts there were large increases from 1953 to 1957 in the amounts of N and K used on tillage and leys, the increases being mainly, but not solely, because a greater proportion of the crop acreage was treated; the absolute increases were smaller for permanent grass, but as a percentage of the 1953 consumption were very large except in the upland grassland districts, where little change occurred. Generally speaking, the proportions of crop acreages receiving phosphorus changed little, but in districts where compound fertilizers are replacing 'straight' P, rates of application of P on grassland were much reduced.

The total amount of farmyard manure produced in England and Wales in 1956–7 is estimated to have been about 50 million tons or just under 2 tons per acre of crops and grass. Except for a small increase in the lowland grassland counties, there has been little change since a previous estimate in 1944.

THE survey of fertilizer practice had its origins in the war years, at a time when information was needed on how farmers made use of their fertilizers, in order to justify the policy of importing fertilizers instead of food.[1] The first two years' results from that inquiry were reported in this journal in 1944 [1]. In view of substantial changes in the total consumption of fertilizers, a further series of surveys was instituted in 1950, and the results were summarized, again in this journal, by Church in 1952 [2]. In 1957 the scope of the survey was greatly extended; in addition to a special effort by the staff of the N.A.A.S. Regional Soil Chemists (who were responsible for all the field work of the earlier surveys), the Fertilizer Manufacturers' Association arranged for surveys to be undertaken by representatives of the fertilizer manufacturers, as a research task independent of their normal activities. More than 2,000 farms were visited during the year, covering forty-five counties or parts of counties, of which ten had not previously been surveyed or had not

[1] The results of almost all past surveys in England and Wales have been issued in mimeographed form by the Ministry of Agriculture. In addition, each year since 1956 surveys in Scotland have been reported jointly by the Agricultural Research Council, Unit of Statistics, Aberdeen, and the three Scottish Colleges of Agriculture.

[Empire Journ. of Exper. Agric., Vol. 29, No. 113, 1961.]

been surveyed for at least ten years. This paper is based on the very comprehensive information obtained on farmers' manurial practice in 1956–7 for thirty-five districts in England and Wales; the districts are listed according to three broad type-of-farming groups in Table 1. Detailed numerical results for the individual districts have been reported by Blood, Harper *et al.* [3] (1958).

TABLE 1. *Districts Surveyed in 1957 and Contributing to Subsequent Tables*

Mainly arable districts (England)	*Mainly grassland districts (lowland England)*	*Grassland districts (Wales and English uplands)*
Yorkshire, E. Riding (High Wolds)	Northumberland (Morpeth–Corbridge district)	Anglesey
Yorkshire, W. Riding (Vale of York)		Montgomery, E. and Central
Lancashire, S.W.	Cumberland, N.W.	Cardiganshire
Shropshire, E.	Lancashire, Fylde	Carmarthen, Central
Lincolnshire, Lindsey, N.W.	Leicester, E.	Monmouth, Central
Nottingham	,, W.	Durham, W.
Northampton, N.E.	Northampton, S.W.	Derby, N.W.
Isle of Ely (peat, silt, and skirt soils)	Gloucester, Cotswolds	Cornwall, N.
Cambridge	Buckingham, Chilterns	
Norfolk, N.W.	Somerset, E.	
,, E. and Central	Devon, S.	
Suffolk, E. (chalky boulder clay soils only)	Sussex (Hailsham area)	
Essex, N.W.	Kent (High Weald)	
Berkshire, N.W. (chalk soils only)		
Kent, N. Downs		

This first part of the paper gives the use of fertilizers on tillage, leys, and permanent grass in 1957 and trends in practice over the last five years, together with estimated supplies of farmyard manure and the crops on which it is used. The second part of the paper will give more detailed information on the manuring of individual tillage crops.

General Features of Fertilizer Consumption

Table 2 gives the average fertilizer application per acre of crops and grass in 1956–7 for three groups of surveyed districts: those with mainly arable farming (based on results from 15 districts); those mainly under grass in lowland England (12 districts); and grassland districts in upland areas of the north and south-west of England and in Wales (8 districts). The figures given for each group of districts are straight means, unweighted by acreage, of those for the individual districts. In arriving at values for England and Wales as a whole, the group means were weighted by the estimated acreages in each group (arable districts 9·5,

lowland grassland districts 9·7, other grassland districts 5·3 million acres).

TABLE 2. *Estimated Average Rates of Fertilizer Application in 1957 and Changes 1953–7, Compared with Official Figures*

(*cwt. per acre of crops and grass*)

District	*Overall average rates*				*Changes 1953–7*			
		P_2O_5				P_2O_5		
	N	*Sol.*	*Insol.*	K_2O	N	*Sol.*	*Insol.*	K_2O
Arable districts	0·35	0·26	0·04	0·38	+0·07	+0·01	−0·01	+0·10
Grassland districts	0·15	0·11	0·11	0·15	+0·02	0·00	−0·02	+0·03
Wales and English uplands	0·07	0·10	0·15	0·09	+0·02	−0·01	−0·02	+0·04
England and Wales: (Survey)	0·21	0·17	0·08	0·23	+0·04	0·00	−0·01	+0·06
(Ministry of Agriculture)	0·19	0·14	0·08	0·18*	+0·04	+0·01	−0·01	+0·05*

* K_2O in 'compounds' only (excludes about 10 per cent. of the total consumption).

The table shows that, in the arable districts, between two and three times as much nitrogen and potassium was applied per acre of crops and grass as in the grassland districts of England and four to five times as much as in upland England and Wales. The ratios are much the same for water soluble P_2O_5, but more basic slag and rock phosphate were used per acre in the grassland districts.

At the right-hand side of Table 2 estimates are given of changes in manuring between 1953 and 1957 based on 10 arable districts, 7 grassland districts, and 4 upland districts which were surveyed in 1952–4 and again in 1957. Where the earlier survey was undertaken in a year other than 1953 the change 1953–7 has been estimated by assuming a linear trend. Trends in practice during 1944–50 and 1951–4, based on earlier and less comprehensive surveys, have been reported by Church [2] and by Church, Blenkinsop *et al.* [4].

Between 1953 and 1957 nitrogen consumption in England and Wales increased by about one-fifth and potash consumption by almost one-third. Increases were greatest in arable farming districts and these accounted for about 60 per cent. of the additional consumption, compared with 30 per cent. for lowland grassland districts and 10 per cent. for the uplands. There was little change in phosphorus consumption between 1953 and 1957, but the use of insoluble phosphates declined slightly in grassland areas.

The total crops and grass acreage of England and Wales did not change between 1953 and 1957, but tillage acreage fell by about 8 per cent. for England and rather more for Wales, with corresponding increases in the acreages under leys and permanent grass. These changes, which included a reduction of one-fifth in the potato acreage, were enough to cause an appreciable decline in the use of nitrogen

and potassium, if their effects had not been counterbalanced by increases in the manuring of individual crops.

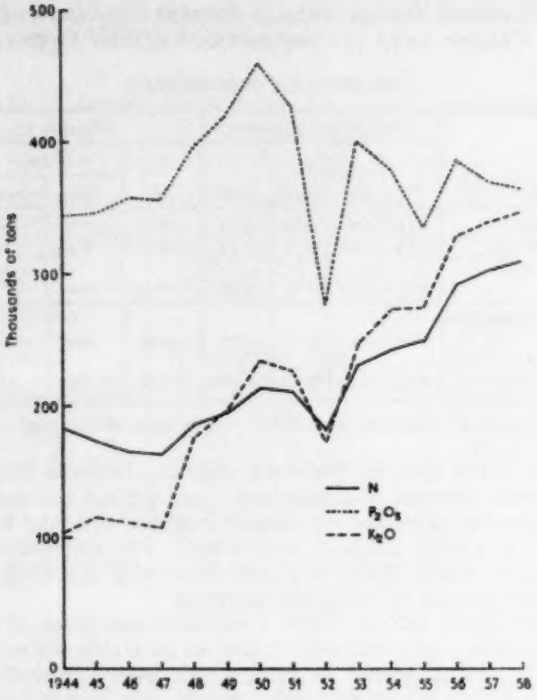

FIG. 1. Fertilizer consumption in the United Kingdom.

The survey estimates of fertilizer consumption for England and Wales as a whole may be compared with those calculated from official statistics based on subsidy payments, which are given at the foot of Table 2; the two sets of figures are not exactly comparable, those for the surveys referring only to holdings of more than 10 acres. The survey estimates are about 10 per cent. higher, but agreement between the two series for 1957 must be considered good and supports the main conclusions derived from the survey. The survey estimates of changes in fertilizer consumption per acre during 1953–7 agree closely with those derived from the official figures.

Fig. 1, based on official statistics of supplies to merchants and farmers for the United Kingdom, illustrates the changes in fertilizer consumption over a more extended period. Separate statistics for England and Wales are available only from 1953 onwards; about 80 per cent. of the nitrogen and 70–75 per cent. of the phosphorus and potassium were used in England and Wales. The figure shows that the

striking increases in the use of nitrogen and potassium since 1953 continue trends which were evident throughout the previous decade; since a peak in 1950, the general trend of phosphorus consumption has been downward. The figure also shows that there were temporary checks to fertilizer consumption in 1951–2 and in 1954–5; the first of these (accentuated in the figure from running down of stocks) is attributable to a sharp increase in the cost of fertilizers to the farmer and the second in part to the exceptionally wet autumn of 1954.

Fertilizers used on Tillage, Leys, and Permanent Grass

The average rates of fertilizer application on leys and permanent grass and the changes in the manuring of these crops during the period 1953–7 are given in Table 3 for each group of surveyed districts. The table also gives figures for tillage; the manuring of individual tillage crops will be discussed in the second part of this paper. In each group of districts very much less fertilizer was used on leys than on tillage, whilst amounts applied to permanent grass were still very low indeed.

TABLE 3. *Average Rates of Fertilizer Application to Tillage, Leys, and Permanent Grass in 1957 and changes 1953–7*

(*cwt. per acre*)

Kind of farming	*Overall average rates 1957*			*Changes 1953–7*		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Tillage						
Arable districts	0·44	0·37	0·52	+0·08	+0·03	+0·14
Grassland districts	0·25	0·30	0·30	+0·04	−0·03	+0·06
Wales and English uplands	0·18	0·42	0·25	+0·06	−0·01	+0·14
England and Wales	0·36	0·36	0·44	+0·07	+0·01	+0·12
Leys						
Arable districts	0·24	0·18	0·17	+0·06	−0·02	+0·03
Grassland districts	0·19	0·24	0·15	+0·03	−0·02	+0·03
Wales and English uplands	0·10	0·31	0·11	+0·04	−0·01	+0·05
England and Wales	0·19	0·24	0·15	+0·04	−0·02	+0·03
Permanent grass						
Arable districts	0·14	0·12	0·08	+0·04	−0·04	+0·03
Grassland districts	0·07	0·16	0·06	+0·02	−0·01	+0·02
Wales and English uplands	0·03	0·18	0·04	0·00	−0·03	+0·01
England and Wales	0·07	0·16	0·06	+0·02	−0·02	+0·02

Compared with lowland grassland districts, the arable districts used more nitrogen, rather more potassium, and less phosphorus on leys and permanent grass. These differences are accentuated when the arable and upland grassland districts are compared. Average rates of application of nitrogen and potassium to tillage crops in grassland districts are not much more than half those in the arable districts. This difference reflects the smaller amount of nutrients removed from

farms in grassland districts by cash cropping, and the lower nitrogen requirements of arable crops in a ley rotation; moreover, supplies of farmyard manure are more plentiful in grassland areas. Compared with the arable districts, rather more phosphorus was used on tillage crops in the uplands and rather less in the lowland grassland districts.

The greatest changes in overall rates of application between 1953 and 1957 have been increases in the amounts of nitrogen and potassium used on tillage and leys, in districts of all types. During this period, increases in overall rates for nitrogen and potassium, on both tillage crops and leys, amounted to between one-fifth and one-third of the 1953 consumption in arable and grassland districts and were proportionately even greater in upland regions. The increases were due mainly to the greater proportions of the crop acreages receiving the nutrients but the average dressings also increased. In relation to 1953 consumption, the increases in nitrogen and potassium in the upland districts were remarkable; they were associated with a trend towards compound fertilizers at the expense of 'straight' phosphorus fertilizers, total phosphorus consumption being virtually the same in 1957 as in 1953.

Compared with the arable crops, the manuring of permanent grass has continued to be at a lower level and the absolute increases in the use of nitrogen and potassium per acre since 1953 have been smaller; even so, overall rates of application to permanent grass in lowland grassland and arable districts increased by about 50 per cent. between 1953 and 1957. There was no corresponding increase in the English upland districts and Wales, where the manuring of permanent grass appears to have changed little since 1953.

Increases in fertilizer consumption in recent years have often been largely attributed to the greater use of fertilizers on grass. However, it can be calculated from Table 3 that, after making allowance for the reduction in tillage acreage, nearly half of the increased nitrogen consumption in 1957 above the 1953 level was used on tillage crops, the remainder being attributable about equally to leys and permanent grass.

The proportions of crop acreages receiving phosphorus fertilizers did not change much between 1953 and 1957 but in some districts there were considerable reductions in rates of application on grassland. Taking the country as a whole, average dressings fell from 0·77 to 0·58 cwt. P_2O_5 per acre on leys, and from 0·68 to 0·51 cwt. P_2O_5 per acre on permanent grass. There has been a general trend away from infrequent heavy dressings of phosphorus for grassland; in the immediate post-war years, average rates of over 1·0 cwt. P_2O_5 per acre were common in parts of the Midlands, Wales, and the North, but are now much less frequent. Practice differs substantially between districts; thus in 1957 in the Fylde district of Lancashire, about three-quarters of the leys received phosphorus, the average dressing being only 0·44 cwt. P_2O_5 per acre, whereas in Northamptonshire the average rate was 0·75 cwt. P_2O_5 per acre, but only a third of the acreage was dressed. It seems probable that the trend towards smaller and more frequent phosphorus dressings will continue for some years, more particularly in the upland districts where rates are still fairly high.

TABLE 4. *The Manuring of Grassland according to Utilization for Hay, Grazing, &c.*

Utilization	*% acreage receiving*				*Average dressing cwt. per acre*		
	FYM	N	P	K	N	P_2O_5	K_2O
Arable districts							
1 year leys	1	37	19	15	0·38	0·61	0·43
2–7 year leys grazed only	3	69	48	36	0·45	0·54	0·52
,, ,, ,, cut for hay	4	65	38	36	0·48	0·45	0·60
Permanent grass grazed only	3	34	24	18	0·40	0·58	0·49
,, ,, cut for hay	10	41	21	14	0·34	0·53	0·44
Grassland districts							
1 year leys	2	54	40	33	0·42	0·48	0·44
2–7 year leys grazed only	10	49	43	32	0·38	0·58	0·42
,, ,, ,, cut for hay	17	55	44	30	0·38	0·54	0·44
,, ,, ,, cut for silage	7	88	74	63	0·48	0·52	0·53
Permanent grass grazed only	6	23	22	13	0·33	0·62	0·41
,, ,, cut for hay	19	33	28	17	0·31	0·69	0·37
Upland districts							
2–7 year leys grazed only	7	27	41	22	0·31	0·76	0·43
,, ,, ,, cut for hay	39	36	48	29	0·31	0·66	0·41
Permanent grass grazed only	6	13	26	11	0·25	0·79	0·40
,, ,, cut for hay	42	20	29	15	0·29	0·61	0·43

The manuring of grassland according to farming type and utilization for hay, grazing, or silage is summarized in Table 4. One-year leys in arable districts, which are often preponderantly red clover, received less fertilizer than the longer leys. In both arable and grassland districts the differences in average manuring of 'hayed' and grazed leys were generally small but fields cut for silage were manured more consistently than other grass fields and received heavier dressings of nitrogen and potassium. Dressings of both farmyard manure and nitrogen were given rather more frequently on permanent grass fields cut for hay than on those fields which were grazed only; however, it is remarkable how large an acreage of grassland cut for hay or silage still receives no fertilizer or farmyard manure.

The influence of farm size on the manuring of leys and permanent grass is given in Table 5 where averages are shown separately for arable, lowland grassland, and other districts. In general, fertilizer consumption per acre increased with size of farm, but much more farmyard manure was used per acre on the smaller farms. When allowance is made for the available nutrients in average farmyard manure [5] the total amount of nutrients applied per acre was much the same whatever the size of farm.

Farmyard Manure

The total amount of farmyard manure (FYM) produced in England and Wales is estimated to have been just under 2 tons per acre of crops and grass or about 47 m. tons in 1956–7. Since a previous estimate

TABLE 5. *The Manuring of Grassland according to Farm Size (overall average rates cwt. N, P_2O_5, K_2O, and tons FYM per acre)*

Acres crops and grass	*Leys*				*Permanent grass*			
	FYM	N	P_2O_5	K_2O	FYM	N	P_2O_5	K_2O
Arable districts								
10–49 . .	(0·3)	(0·23)	(0·18)	(0·12)	1·2	0·13	0·05	0·04
50–149 . .	0·6	0·24	0·18	0·14	0·3	0·12	0·13	0·04
150–299 . .	0·2	0·23	0·19	0·16	0·1	0·15	0·14	0·09
300+ . .	0·0	0·23	0·20	0·19	0·1	0·18	0·15	0·11
Grassland districts								
10–49 . .	3·7	0·13	0·22	0·12	1·6	0·06	0·13	0·04
50–149 . .	1·8	0·16	0·19	0·12	1·1	0·06	0·13	0·05
150–299 . .	1·6	0·18	0·25	0·14	0·9	0·09	0·14	0·07
300+ . .	0·6	0·22	0·26	0·16	0·1	0·07	0·20	0·06
Upland districts								
10–49 . .	3·2	0·07	0·41	0·10	2·5	0·03	0·17	0·04
50–149 . .	2·5	0·10	0·30	0·09	1·4	0·03	0·21	0·04
150+ . .	1·4	0·13	0·40	0·12	0·9	0·04	0·25	0·03

Figures in parentheses indicate estimates based on few districts.

by Yates, Boyd, and Mathison in 1944 [1] there has been a small increase from 1·7 to 1·9 tons per acre of crops and grass, or 13 per cent. In the same period the number of cattle has increased by 18 per cent. (dairy cattle, 10 per cent.), but there has been a sharp falling off in working horses. Since 1944 there appears to have been little change in the amount of FYM applied in the arable farming districts of England, but a definite increase in the lowland grassland counties.

In 1957 the amounts applied per acre crops and grass were about 1·4 tons in the arable districts, 2·0 tons in the upland districts, and 2·4 tons in the lowland grassland districts. In addition to these differences associated with farming type, there were considerable differences in different regions. Many parts of the north had between 2 and 4 tons FYM per acre of crops and grass, whereas parts of the East Anglian counties and some other arable districts (e.g. the Cotswolds and the Berkshire and Wiltshire Downs) had less than 1 ton per acre. The midland counties (e.g. Leicestershire and Northants.) had only about 1 ton FYM per acre of crops and grass.

Table 6 shows the distribution of the available FYM between the main crop groups. In the more arable counties, all but a small part of the FYM was applied to tillage crops, compared with about half in the grassland counties and a fifth in the upland areas. In the uplands the FYM was mainly applied to fields shut up for hay, particularly permanent meadows.

Table 6 also shows the proportions of the total acreages under different crops which received FYM. As might be expected, the proportion of the potato acreage receiving FYM was greatest in lowland

TABLE 6. *The Distribution of Farmyard Manure between Crops*

	Percentage of total FYM supplies used on crop			*Percentage of crop acreage dressed*		
	Arable districts	*Lowland grassland districts*	*Other grassland districts*	*Arable districts*	*Lowland grassland districts*	*Other grassland districts*
Cereals . .	20	14	4	6	8	10
Potatoes . .	21	7	2	44	82	66
Sugar-beet . .	16	0	0	38	—	—
Other roots and green crops .	15	25	13	—	—	—
Market garden, fruit and legumes	12	1	0	—	—	—
All tillage . .	84	47	19	14	20	22
Grass mown .	8	31	63	7	22	41
Grass grazed only	8	22	18	3	8	7
	100	100	100			

grassland districts where the area of the crop grown was small in relation to FYM supplies. Less than half the potato and sugar-beet acreage in arable farming districts received FYM; indeed, the total quantity used on cereals in these districts was about equal to that used on potatoes. However, the group of arable districts includes some, like Cambridgeshire, where potatoes are of secondary importance to cereals, and the survey results show that those districts where potato or sugar-beet growing is particularly important generally used less FYM for cereals than did other arable farming districts. Similarly, within a district, farms which grow potatoes or sugar beet generally reserved their supplies of FYM for these crops. However, the survey results indicate that cereals sometimes compete with potatoes and sugar-beet for FYM supplies to a surprising extent. In east Northamptonshire, although only half the potato acreage was dunged, a somewhat greater total quantity of FYM was used on 7 per cent. of the cereal acreage. Of the fourteen sampled farms in this district which are known to have used FYM on cereals, five grew no cash roots, but on each of the other nine farms there was at least one field under potatoes or sugar beet which did not receive FYM. It is clear from this example that cash roots do not always get first priority in the use of FYM on arable farms where supplies are limited.

Before 1939 FYM provided a major part of the nutrients applied on most farms, but since then there has been only a small increase in amounts of FYM to set against the large changes in fertilizer consumption. Taking recent estimates by Boyd [5] of the average effective amounts of nitrogen, phosphorus, and potassium in FYM in the year of application, it appears that, in England and Wales in 1957, FYM provided about one-fifth of the nitrogen, one-quarter of the phosphorus, and two-fifths of the potassium applied to crops.

	(*cwt. per acre of crops and grass*)		
	N	P_2O_5	K_2O
From FYM . .	0·05	0·08	0·14
From fertilizers . .	0·19	0·23	0·19

Within-farm comparisons of the amounts of fertilizer applied to crops grown with FYM and those grown without FYM have consistently failed to show any real difference (Boyd [5, 6]); it is scarcely open to doubt that farmers with good supplies of FYM could save considerably on their fertilizer bill by paying regard to the immediately available nutrients contributed by FYM.

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(*Received 20 November 1959*)

NOTE ON ARTIFICIAL INDUCTION OF LACTATION IN BUFFALOES

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Summary

This preliminary report shows that the subcutaneous injection of hexettes stimulated udder and teat growth and also initiated lactation in two buffalo heifers. Lactation then ceased with one heifer, but after injection of oxytocic hormone lactation was maintained by the other heifer. The milk so obtained was quite similar to normal buffaloes' milk.

EXPERIMENTAL evidence has long been in existence which indicates that the development and secretory activity of the mammary gland is controlled by hormonal rather than neural mechanisms, but recent work suggests that nervous influences may be involved in the secretion of pituitary hormones concerned in lactation and particularly in the ejection of milk from the mammary gland. Many species respond to oestrogen at moderate dosage levels by duct growth; often, especially when the treatment is prolonged, accompanied by a limited amount of alveolar proliferation. In other species there is evidence, much of it indirect, that oestrogen alone will evoke extensive, if not complete, alveolar development. In ruminants there is much evidence, mainly indirect, that oestrogen will evoke development of alveoli in addition to the duct system. In the virgin female goat treatment with oestrogen alone will cause the development of an udder capable of copious lactation [1, 2, 3, 4, 5, 6]. Even more spectacular results along similar lines have been obtained in bovines by Walker and Stanley [7, 8], Folley, Scott Watson, and Bottomley [9], Reece [10], Folley and Malpress [11], Folley, Stewart, and Young [12], Hammond, jnr., and Day [13], Parkes and Glover [14], and Folley *et al.* [5], synthetic oestrogens being used exclusively in these investigations. The milk yields obtained, in some cases exceeding 3 gallons daily, could be produced only by abundant alveolar tissue, and macroscopic examination of whole mounts of udder slices from oestrogen-treated heifers (Folley and Malpress [11]; Hammond, jnr., and Day [13]) showed that considerable lobule-alveolar growth had occurred. Successful induction of lactation in a spayed heifer [7, 8] and in a freemartin [11] indicates that in bovines oestrogen will promote alveolar development in the absence of ovarian progesterone.

Similar investigations have not been carried out in buffaloes; it was therefore thought desirable to make some observations on the effectiveness of hormones in inducing and maintaining lactation in buffalo cows.

[Empire Journ. of Exper. Agric., Vol. 29, No. 113, 1961.]

Experimental

Two buffalo heifers were used in this study, of ages 18 and 15 months respectively. In the first heifer 60 mg. of hexettes (Cooper's) pellets (*Hexoestrol/stilboesterol*) were implanted subcutaneously in the caudal third of the neck, followed 6 weeks later by a subcutaneous injection of the same hormone in an oily solution, the dosages being 10, 15, 20, and 25 mg. Each dose was administered twice weekly for 2 weeks. In the second heifer 5 mg. of hexettes in an oily solution were injected subcutaneously twice weekly for 6 weeks, followed by 10, 15, 20 mg., each given twice weekly for 2 weeks and 25 mg. injected twice weekly for 6 weeks. Observations were made on the development of the udder together with sexual behaviour and the general condition of the animals. Milking was begun the first day after the last injection. The milk was weighed and analysed by the methods of the Association of Official Agricultural Chemists (1930 edition) in the U.S.A. for fat, total protein, albumen and globulin, lactose, ash, total solids, and water. Comparison was made between the artificially induced milk and a sample of normal milk collected from 200 buffalo cows. With the second buffalo heifer 50 I.U. oxytocic hormone were administered on the second milking day.

Results

In both heifers there was a slight increase in udder and teat size and then the udder appeared to become slightly filled with secretion. The secretion, however, was not removed and the activity seemed to subside. By the end of the injection period the udders had increased considerably in size although they were not distended with secretion. The first heifer was milked the first day after the last injection, the milk yield being 95 gm. On the second day of milking the animal gave a few drops and no more milk could be obtained from her thereafter in spite of all efforts to maintain lactation.

The second heifer milked 80 gm. on the first day after the last injection, on the second day 50 I.U. of oxytocic hormone was injected when milking was found to be difficult. The animal was then milked with no difficulty and the milk yield increased gradually as shown in Fig. 1. The milk obtained on the first 3 days was similar to colostrum in appearance and was high in solids-not-fat. The milk was normal in appearance on the fourth day. The composition of the milk obtained from the oestrogen-treated buffalo heifer and of that obtained from non-oestrogen-treated buffalo cows are compared in Table 1.

The sexual behaviour of both heifers during the hormone treatment period was in the form of intense heat which started 10 days after implantation in the first heifer and on the second day from the first injection in the second heifer. As the dose of hormone was increased the animal's behaviour became more bull-like rather than similar to that of a buffalo cow in intense oestrus. Rectal palpation of the ovaries in both heifers before and during the treatment period did not reveal the occurrence of any ovarian cysts. The vulva in both heifers was found to be congested, swollen, and tumified during the injection period.

Further work is being carried out to investigate the hormonal mechanism of lactation in the buffalo cow.

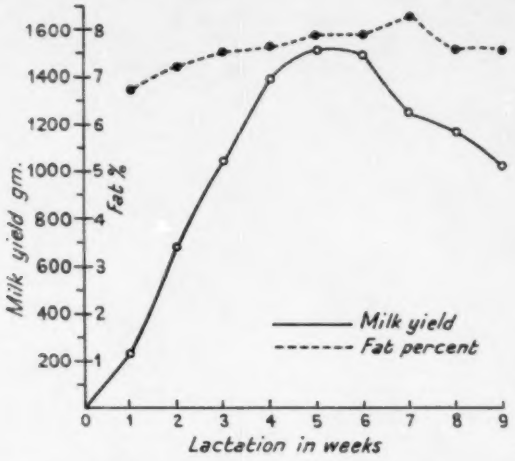

FIG. 1. Showing the average milk yield and fat percentage of an oestrogen-treated buffalo heifer.

TABLE 1. *The Constituents of Milk from an Oestrogen-treated Buffalo Heifer and non-Oestrogen-treated Buffalo Cows*

Treatment	*Milking*	*Total protein* %	*Casein* %	*Albumen and globulin* %	*Lactose* %	*Fat* %	*Ash* %	*Total solids* %	*Water*
Oestrogen-treated buffalo heifer	1st day	32·15	1·43	30·72	0·74	6·0	54·5	93·4	6·6
	2nd day	26·62	1·43	25·19	2·23	10·0	53·15	92·0	8·0
	3rd day	14·11	4·72	9·39	2·68	5·0	8·21	29·9	70
	4th day	8·38	5·07	3·31	3·53	6·5	1·59	20·0	80
	5th day	5·93	2·36	3·57	3·19	7·5	1·08	17·7	82·3
	6th day	4·91	3·75	1·16	3·53	5·5	0·66	14·5	85·5
	16th day	4·86	3·50	1·36	3·94	7·0	0·6	14·4	85·6
Non-oestrogen-treated buffalo cows	Morning and evening	3·55	2·02	1·53	4·86	7·2	1·37	17·0	83·0

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(*Received 16 October 1959*)

NOTE ON THE EFFECT OF METABISULPHITE ON THE SUGAR CONTENT OF ENSILED ORANGE PEEL[1]

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THE use of ensiled orange peel in Israel as a suitable food for cows was investigated by Bondi [1] and Volcani [2] several years ago.

In the present trial sodium metabisulphite was used as a preserving agent in making silage from orange peel. Murdoch *et al.* [3] found that metabisulphite preserved carbohydrates in ensiled grass. The authors' results confirm this finding, as applied to orange peel alone, or mixed with lucerne.

TABLE 1. *Analyses of Orange Peel Silages*
(*sugar content expressed on air-dried material*)

Barrel no.	*Material ensiled*	*pH*	*D.M. content* %	*Total sugars* %	*Mono-saccharides* %	*Disaccharides* %
	Fresh orange peel (before ensiling)	4·30	20·2	24·6	19·4	5·2
1	Orange peel+0·5% metabisulphite	3·20	24·6	17·7	15·3	2·4
2	Orange peel alone	3·05	16·0	2·2	2·2	0·0
3	Orange peel+ 4·5 kg. hay	3·00	20·0	2·5	2·5	Traces
4	Orange peel+ 18 kg. lucerne	3·30	17·2	1·4	1·4	0·0
5	Orange peel+ 16 kg. lucerne+ 0·5% metabisulphite	3·60	19·2	18·4	14·7	3·7

Five barrels were filled with fresh orange peel, from a nearby factory. Barrels nos. 1 and 2 were filled with peel only, Barrel no. 3 also contained 4·5 kg. of hay, composed of vetch and oats. Fresh chopped lucerne was added, in three layers, to two barrels; 18 kg. to no. 4 and 16 kg. to no. 5. Barrels nos. 1 and 5 also received 0·5 per cent. metabisulphite.

The resulting silages, after a period of 10 weeks in the barrels, were analysed. The results are presented in Table 1.

From the low pH values it may be seen that fermentation was normal. The silages from peel alone or mixed with hay, without metabisulphite,

[1] Publication of the Agricultural Research Station, Rehovot-Beit Dagon, 1959 Series, No. 296-E.

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[Empire Journ. of Exper. Agric., Vol. 29, No. 113, 1961.]

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had the lowest pH value; the silage from peel mixed with alfalfa had somewhat higher pH values.

The sugar content of the metabisulphite-treated silages was considerably higher than that of the silages made without metabisulphite. Seventy-two per cent. of the sugar contained in fresh peel was preserved in treatment no. 1 and 75 per cent. in no. 5. In the other treatments only an average of 8 per cent. of sugars was preserved. The influence of the metabisulphite was also demonstrated by the fact that the disaccharides disappeared in all the metabisulphite-free treatments, whereas in the metabisulphite-treated silage a certain amount of the disaccharides was preserved.

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(*Received 18 September 1959*)

THE EFFECT OF IRRIGATION ON NODULATION OF SOME LEGUMINOUS CROPS

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Summary

The effect of irrigation on nodulation of certain legumes was studied in the field over four seasons on a clay soil at Oxford. The main crops used were *Vicia faba*, *Pisum sativum*, and *Phaseolus vulgaris*. Irrigation water was applied at regular intervals irrespective of weather conditions, but in lesser quantities when the soil was wet.

The results show that irrigation may in this environment increase the weight of plants in a dry season, or more rarely depress it in a wet one. The number of nodules was increased by irrigation in all experiments but one, though not all the increases attain statistical significance. The weight of nodules on the plants showed an increase in all cases, more of the results being significant. Analysis of the figures shows that irrigation generally increased the size as well as the number of nodules, though not usually by so large a percentage.

With *Vicia faba* and *Pisum sativum*, whose nodules are attacked by larvae of the weevil *Sitona lineata*, irrigation effected a useful degree of control of these larvae and so prolonged the life of the nodules.

There are indications that it would be worth while to look more fully into the possibility that irrigation may in suitable circumstances confer more benefit on nodulated legumes than on other crops, due to its effect in causing an improvement of nodulation.

In field surveys of the nodulation of leguminous crops in various countries, the circumstantial evidence gathered indicates that, in general, nodulation is greatest where soils are wettest [1, 2]. At the opposite extreme of precision, a number of research workers have shown from pot experiments with carefully regulated soil moisture contents that number of nodules increases with increasing soil moisture up to high values; this work has been summarized by Fred, Baldwin, and McCoy [3]. Between these two extremes of precision, there is a lack of information on the practical effect of irrigation on the nodulation of leguminous crops under field conditions. The purpose of the investigation described in this paper was to obtain information on this subject.

Experimental Methods

All the experiments were carried out on a clay soil at the Oxford University Field Station. Since only very small numbers of plants can be examined in detail for nodulation, micro-plots were used, each individual plot being from 6 to 9 square feet in different experiments, and containing only one or two rows of plants. The experimental areas were prepared for irrigation by surrounding each plot by an earth bank 18 inches wide in the earlier experiments, and 1 foot wide in later ones. Some anxiety was felt at the beginning lest the water applied to the

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irrigated plots should by lateral seepage affect also the plants in neighbouring non-irrigated plots. In the outcome it proved that seepage could have had no appreciable effect in increasing the nodulation of plants in the non-irrigated plots, since the mean figures for nodule weights for such plants were very close to the means observed for the same crops in the same fields in several years of previous experimentation without irrigation.

Irrigation water was applied at the surface by a hose from standpipes. The amount of water applied was approximately measured by timing the operation and then timing the filling of a 5-gallon drum with the tap at the same setting; within the limits of accuracy of this method of measurement, the water pressure, which is controlled by a storage tank on the Field Station, proved not to vary during applications.

Irrigation of the appropriate plots was not begun until the plants had emerged, so that there should be no differential effects on the time of germination of the crop. Once begun, it was carried out once a week until the plants were lifted for examination. At each irrigation, water was applied until it stood above the surface of the soil and either reached the lowest leaves of the crop or stood 1 inch deep where it was deepest, whichever occurred first. This procedure was, of course, purely empirical, but it was thought that it would have the following advantages:

1. It would lead to the application of quantities of water within the range of those used in normal irrigation practice in different countries—which indeed proved to be the case.
2. It would relate the amount of water applied, however roughly, to the absorptive capacity of the soil at the time, as would be done in normal practice.
3. It would ensure that some water was applied even in very wet weather, thus giving the chance of making observations on the effect of what would be an excess of water in farming practice.

For detailed examination of the degree of nodulation, five plants selected at random were taken as a sample from each plot. These plants were uprooted as nearly as could be judged at the peak of the flowering period, when nodulation can be expected to be at its maximum. Full details of the method of examination have been given in an earlier paper [1]. Briefly, the root systems of the plants are carefully excavated with a garden fork, a hose being played on them at the same time if the soil is particularly hard. After the root systems have been washed, the plants are examined in the laboratory. In counting nodules, any cluster of confluent nodules is counted as one nodule, and any nodules too small to be detachable with fine forceps are not counted; the figures for numbers of nodules thus err on the low side, but are comparable among themselves.

The varieties of crops used were as follows:

Field beans (*Vicia faba*): stock seed of unnamed strains of winter and spring beans as grown at the Field Station.

Peas (*Pisum sativum*): the dwarf early variety 'Sharpe's Meteor', and in the 1959 experiment the similar variety 'Peter Pan'.

Dwarf French beans (*Phaseolus vulgaris*): 'Canadian Wonder'.
Soya beans (*Glycine soja*): 'Fiskeby III', seed kindly supplied by Algot Holmberg and Sons, Norrköping, Sweden.

Preliminary Experiments

Two preliminary experiments were carried out in 1955–6; one on winter beans (*Vicia faba*) sown in October 1955, and one on peas sown in March 1956. The same four treatments were applied to both crops:

1. Weekly irrigation throughout the nodule-growing period from emergence to flowering. Irrigation of the winter beans was suspended during the winter when the plants and nodules were not growing, from mid-December to late March.
2. Early irrigation only, i.e. during the first half (as nearly as could be judged) of the nodule-growing period. The winter beans received four irrigations before the winter suspension, and one in the spring.
3. Late irrigation only, during the second half of the nodule-growing period.
4. Control, no irrigation.

There were three replications of each treatment, in a randomized block layout.

The results of these experiments are shown in Table 1.

TABLE 1. *Effect of Irrigation at Different Periods on Nodulation*

Treatment	*Mean fresh weight (g.) of*		*Mean no. of nodules per plant*
	Plants	*Nodules per plant*	
	Winter beans		
Continuous irrigation .	70·4	1·62	70
Early irrigation . .	58·3	1·00	57
Late irrigation . .	73·8	1·72	72
No irrigation . .	51·6	0·87	50
	Peas		
Continuous irrigation .	5·2	0·16	39
Early irrigation . .	4·6	0·10	27
Late irrigation . .	5·3	0·15	38
No irrigation . .	3·8	0·06	28

While all the irrigation treatments, and especially late and continuous irrigation, appear to have increased the weight of plants and nodules, and the number of nodules, in both crops, none of these differences attain statistical significance.

Two conclusions were drawn from these preliminary experiments: firstly, that statistically significant differences were most likely to be attained by employing irrigation throughout the period from emergence

to flowering or during the latter half of this period; and secondly, that in view of the high degree of variability of the material it was imperative to cut down the number of treatments and to increase the number of replications up to the maximum of plots that could conveniently be irrigated from one stand-pipe.

Main Experiments

In this series, experiments of a uniform design were carried out on three crops in the years 1957, 1958, and 1959. In view of the findings in the preliminary experiments, the number of replications was increased to eight, in a randomized block layout. The number of treatments was reduced to two:

(*a*) No irrigation (hereafter referred to as the 'control' treatment).
(*b*) Weekly irrigation from emergence to flowering, but (in view of the suggestion from the preliminary experiments of the small value of early irrigation) with sufficient delay before irrigation was begun to make sure that emergence was quite complete.

There was thus no variation of the irrigation treatment, but as the experiments were spread over three years differing weather conditions caused variations in the amount of water applied and gave a chance to observe differing reactions by the plants.

The three crops used were spring beans (*Vicia faba*), dwarf French beans, and peas. In 1957 peas, and in 1958 French beans, were sown at two different dates to increase the chance of obtaining variations in weather conditions. In 1959 soya beans, which were being grown for the purpose of other observations, were included in the experiments; as this crop does not normally nodulate in England, the seed was inoculated with a culture of the appropriate Rhizobium obtained from Rothamsted Experimental Station.

Results

Plant Weights

Table 2 shows the effect of irrigation on the fresh weight of whole plants at flowering time in these experiments. The same table includes an indication of the weather conditions during the growing season of each crop; 1959 was a hot dry summer, while 1957 and 1958 were wet or 'normal' for the English summer with the exception of a dry spell in the early summer of 1957 which coincided with the growing period of the spring beans and the first-sown pea crop. Also included is the total amount of water applied to the irrigated plots in each crop. In a dry hot season the amount of water applied is not proportional to the increased absorptive capacity of the soil because the crops mature more quickly and hence fewer weekly irrigations are given. In the same way the second pea crop of 1957 received little water because dwarf peas sown at this time of year mature so quickly. The figures in Table 2 show that there were few statistically significant differences in plant weight due to irrigation: three increases in dry seasons; and one decrease in a wet season, presumably due to an excess of water.

TABLE 2. *Effect of Irrigation on Plant Weight*

Year	Crop	Type of Weather	Amount of water applied (in.)	Mean fresh wt. (g.) per plant	
				Control	Irrigated
1957	Peas (sown May)	Dry	14·4	12·7	14·8
,,	Peas (sown June)	Normal	3·8	5·7	6·2
,,	Spring beans	Dry, hot	17·2	80·5	120·1*
,,	French beans	Wet	13·6	38·6	26·6*
1958	Peas	Normal	8·6	16·5	15·1
,,	Spring beans	,,	14·5	101·4	107·5
,,	French beans (sown April)	Very wet	11·3	28·4	20·4
,,	French beans (sown June)	,, ,,	12·4	58·2	46·1
1959	Spring beans	Dry, warm	13·3	67·6	73·9
,,	Peas	Dry, hot	8·0	29·3	43·6†
,,	French beans	,, ,,	8·4	17·3	28·1
,,	Soya beans	,, ,,	10·5	24·0	46·9*

* Significantly different from control at $P = 0.05$.
† Significantly different from control at $P = 0.01$.

Nodule Numbers

The effect of irrigation on the number of nodules per plant is shown in Table 3. In every case except one there was an apparent increase in nodule numbers due to irrigation, and in four cases (all in dry seasons) the increase is statistically significant. The percentage increase in nodule numbers in these four cases ranges from 90 to 238 per cent.

TABLE 3. *Effect of Irrigation on Numbers and Weights of Nodules*

Year	Crop	Mean no. of nodules per plant		Mean fresh wt. (g.) of nodules per plant	
		Control	Irrigated	Control	Irrigated
1957	Peas (sown May)	16	20	0·07	0·17†
,,	Peas (sown June)	14	18	0·10	0·14
,,	Spring beans	66	125*	0·64	1·63†
,,	French beans	30	34	0·53	0·59
1958	Peas	25	38	0·16	0·26
,,	Spring beans	95	115	1·18	1·69†
,,	French beans (sown April)	6	5	0·08	0·13
,,	French beans (sown June)	20	45	0·22	0·59
1959	Spring beans	64	119*	0·68	1·42*
,,	Peas	11	27†	0·04	0·19†
,,	French beans	27	93†	0·22	0·87†
,,	Soya beans	0·1	0·7	0·002	0·03

* Significantly different from control at $P = 0.05$.
† Significantly different from control at $P = 0.01$.

Nodule Weight and Size

The effect of irrigation on the fresh weight of nodules per plant is also shown in Table 3. There was an apparent increase due to irrigation in every case, and in six of the experiments this increase attains statistical significance, the significant increases in weight ranging from 44 to 391 per cent. This is a larger proportion of significant results than for nodule numbers, and the degree of statistical significance attained is generally higher.

Table 3 shows that in nearly all the experiments, the weight of nodules per plant has increased more than can be accounted for by the increase in nodule numbers. Hence nodule size, as well as nodule numbers, has been augmented by irrigation, and figures illustrating this more clearly have been set out in Table 4. It is apparent that the mean weight per nodule has been increased by irrigation in every experiment but one, though the gain was usually less than that in nodule numbers.

TABLE 4. *Percentage Increase by Irrigation in Numbers of Nodules, and Weight per Nodule*

Year	*Crop*	*Percentage increase by irrigation in*	
		No. of nodules per plant	*Mean wt. of one nodule*
1957	Peas (sown May)	21·8	93·2
,,	Peas (sown June)	31·4	9·0
,,	Spring beans	89·7	34·0
,,	French beans	13·5	decrease
1958	Peas	54·1	6·2
,,	Spring beans	20·8	18·5
,,	French beans (sown April)	decrease	95·5
,,	French beans (sown June)	123·1	18·2
1959	Spring beans	84·4	12·2
,,	Peas	156·6	93·5
,,	French beans	238·2	14·8
,,	Soya beans	338·5	135·0

Sitona Damage and Rate of Decay of Nodules

In England the nodules of *Vicia faba* and *Pisum sativum* are regularly attacked by larvae of the weevil *Sitona lineata*, and a large number are prematurely destroyed. It was, therefore, of interest to observe the effect of irrigation on *Sitona* attack, and this was done in two ways. A record was kept of the percentage of nodules decayed at the time of examining the plants, though as the criteria used for 'decay' were very conservative (i.e. that the nodules should have become flaccid and turned blackish), and as nodules already totally decayed and sloughed off were not recovered, these figures underestimate the absolute amount of damage.

Figures were also recorded in the later experiments for the number of Sitona larvae actually found in nodules during examination, though again this does not reflect their total incidence since many had already left the nodules or would have attacked them later. These figures are shown in Table 5.

TABLE 5. *Decay of Nodules and Presence of Sitona*

Year	Crop	Per cent. nodules decayed		Sitona larvae per 1,000 nodules	
		Control	Irrigated	Control	Irrigated
1957	Peas (sown May)	37·3	25·7	not recorded	
,,	Peas (sown June)	4·5	4·3	,,	,,
,,	Spring beans	24·2	11·9†	,,	,,
1958	Peas	12·5	4·4*	22·2	4·5
,,	Spring beans	9·3	4·5†	14·1	7·0*
1959	Spring beans	14·8	3·4†	42·1	5·1†
,,	Peas	23·5	14·7*	negligible	

* Significantly different from control at $P = 0.05$.
† Significantly different from control at $P = 0.01$.

From Table 5 it is evident that the percentage of decayed nodules was always less in the irrigated plots, the decrease being statistically significant (after angular transformation of the data) in most cases. This difference seems to be adequately accounted for by the decline in the numbers of Sitona with irrigation, which again is consistent and usually significant. In fact the degree of Sitona control obtained by irrigation was rather greater than that achieved by insecticides in an earlier investigation [4]. The reason why only one Sitona larva was found in the pea crop of 1959, where a high percentage of nodules were decayed, is obscure; possibly the larvae had left the nodules early due to some unknown ecological factor.

In the crops of French beans, whose nodules are not attacked by Sitona, the number of nodules found decayed at the time of examination was negligible, never reaching 1 per cent.

Nitrogen Content of Seed

In those cases where irrigation had produced a significant increase in weight of nodules on the plants, it seemed of interest to know whether this had led to an increased nitrogen content of the seeds at the time of harvest. In two of these experiments, some plants were left standing in the plots, but without further irrigation after flowering, until the seed could be harvested from them at maturity. The results of nitrogen analysis of these samples are shown in Table 6. One shows a slightly higher nitrogen content from the control plots, but the differences are not statistically significant.

TABLE 6. *Effect of Irrigation on Nitrogen Content of Seed*

Year	Crop	N per cent. on dry matter	
		Control	Irrigated
1957	Peas (sown May)	4·03	3·89
1958	Spring beans	4·89	4·85

Interaction between Irrigation and Nodulation

The question may well be asked, whether an increase of nodulation in irrigated plots is merely due to the irrigated plants having a larger root system, providing more sites for nodulation, or larger shoots, providing a greater carbohydrate supply for the nodule bacteria. The data presented here provide some evidence that these explanations are not adequate, for the increase in weight of nodules is in all cases proportionately much greater than the increase in plant weight due to irrigation; in fact, in four experiments a greater weight of nodules was obtained from plants which were actually smaller in the irrigated plots.

Some further light is thrown on this question by the fact that two crops without nodules were included, for the purpose of other observations, in the irrigation experiments. One of these was a non-legume, a crop of spring oats, which were sown in the same plots as the spring beans of the 1959 experiment; juxtapositions of oats to beans, even closer than this, have been shown in previous experiments [4] not to affect the nodulation of the latter crop. The other crop was also sown in 1959, soya beans, which did not nodulate because the seed was not inoculated. This could not be sown in the same plots as the inoculated soya beans because of the risk of cross-infection by Rhizobium in irrigated soil, but was sited in an adjacent field on similar soil, sown on the same day and received almost the same amount of irrigation water (11·5 as against 10·5 in.). The effect of irrigation on plant weight in these two crops is shown in Table 7.

TABLE 7. *Effect of Irrigation on Crops without Nodules*

Year	*Crop*	*Mean fresh weight per plant (g.)*	
		Control	*Irrigated*
1959	Spring oats . . .	30·3	25·6•
,,	Soya beans (uninoculated) .	21·3	31·3

• Significantly different from control at $P = 0.05$.

From these figures it will be seen that the weight of the oat plants was significantly depressed by irrigation, while the bean plants (Table 2) grown in the same plots, sown and sampled on the same days, and receiving the same irrigation displayed no significant difference (actually a slight increase, on the crude figures) in weight due to irrigation. For the soya beans without inoculation, irrigation showed a slight but not significant increase in weight, whereas in the paired experiment the inoculated soya beans (Table 2) showed a larger and significant increase. These data, slight in themselves, suggest that it is well worth looking into the possibility that nodulated legumes may receive more benefit from irrigation than do crops without nodules under the same conditions.

Discussion

These experiments were carried out on a retentive clay soil in a humid climate, where irrigation could least be expected to show large effects.

The beneficial effect of irrigation on nodulation, which could often be demonstrated under these conditions and especially in the drier seasons, would be more likely to occur on lighter soils and in the drier climates where irrigation is more often practised.

The fact that on occasion nodule numbers or weights were as much as doubled by irrigation without achieving statistical significance is a recurrent type of difficulty in investigations on nodulation. The variation in these figures between plots is very great, and a part of this variation is accounted for by differences between individual plants. Two or three plants, either very heavily nodulated or without any nodules, can largely contribute to a high standard error. Such plants are frequently found in French beans and peas, much less frequently in *Vicia faba*, for which crop all differences in nodule weights and all but one in nodule numbers in the main experiments were significant. Thus for weights of nodules (the most important aspect studied) in the main experiments, coefficients of variation ranged for peas from 39·8 to 61·5, for French beans from 37·8 to 99·5, but for *Vicia faba* only from 20·2 to 42·1. For the inoculated soya beans, this coefficient reached a value of 156·2, which is no doubt due to the haphazard incidence of nodulation on inoculated plants.

Acknowledgement. The author is indebted to Professor G. E. Blackman for his advice on these investigations and for the provision of all necessary facilities. Nitrogen analyses were carried out by Mrs. S. Bouwer.

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(*Received 15 October 1959*)

CULTIVATION OF *VICIA FABA* L. IN NORTHERN SUDAN

F. T. LAST[1] AND M. A. NOUR[2]

Summary

Winter-sown broad beans in the north of the Sudan became heavily infected with *Leveillula taurica*, *Erysiphe umbelliferarum*, and *E. polygoni*. Spraying with lime sulphur, two or three times per season, decreased the incidence of these powdery mildews, and increased yields by 23 per cent. Sulphur sprays were as effective as lime sulphur but Karathane did not significantly increase yields.

Spraying increased the yields most with beans sown at the optimal date. Varying the concentrations of lime sulphur from 1 in 80 to 1 in 120 v/v, and increasing the frequency of spraying from every third week to weekly did not affect yields.

At Shambat the highest yields, in two of three experiments, were given by crops sown at the beginning of November—earlier sowings are usually severely infested by insects. At Zeidab, 170 miles north of Shambat, high yields were given by crops sown from mid-October to early November. The yields of delayed plantings were much lower.

Nitrogen fertilizer significantly increased mean yields. The increases were twice as large on sprayed as on unsprayed crops, and were smaller on crops sown at the optimum time than on those sown on other dates. Phosphorus and potassium separately did not affect yields but together they increased them as much as nitrogen.

At Shambat, doubling the usual seed-rate of the local variety of beans increased yields by 48 per cent. On introduced varieties, which yielded less, the effect was smaller.

BROAD BEANS, *Vicia faba* L. (= *Faba bona* Medic. [1]), grown during the winter in northern Sudan, often become heavily infected by *Leveillula taurica* (Lév.) Arn., *Erysiphe umbelliferarum* de Bary, and *E. polygoni* DC. [2, 3]. From a range of materials tested, Nour [4] found that elemental and inorganic compounds of sulphur controlled these powdery mildews and increased yields. Elsewhere the incidence of other powdery mildews has been found to be affected by cultural practices, such as changes in spacing [5], date of sowing [6], and fertilizer applications [7, 8]. Experiments were therefore done at two sites in the Sudan to compare the effects of cultural and fungicidal treatments on the incidence of powdery mildews and on bean yields. The two sites, Shambat and Zeidab, near the River Nile, are respectively about 5 and 175 miles north-east of Khartoum.

Materials and Methods

Groups of about five seeds were planted at intervals of 40 cm. along ridges spaced 70 cm. apart. In 1956–7 untreated seeds were planted

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[Empire Journ. of Exper. Agric., Vol. 29, No. 113, 1961.]

at both Shambat and Zeidab; in 1957–8 and 1958–9 seeds sown at Zeidab were treated with a fungicide–insecticide mixture to decrease damage by soil-borne pests and diseases. The mixture of an organic fungicide containing 1·0 per cent. mercury, with 20 per cent. gamma B.H.C. was dusted at a rate of 1:450 w/w of seed [9].

Seedlings emerged about five days after planting, regardless of date of sowing, and were irrigated fortnightly until harvesting was completed, usually by mid-March at Zeidab and two weeks later at Shambat.

The range of treatments tested covered

(1) Varieties of *V. faba*.
(2) Rates of sowing.
(3) Fungicidal sprays.
(4) Dates of sowing.
(5) Fertilizers supplying N, P, and K.

Varieties of V. faba

The respective local strains were used at Zeidab and Shambat. In expts. 7 and 8 the local Shambat strain, B.F.M., was tested against R34 and R40,[1] both introduced from the United Arab Republic.

Rates of Sowing

Seeds were usually planted along the tops of ridges and at intervals of 40 cm. (= about 70 lb. seed/acre). When the rate was doubled, they were planted in groups 20 cm. apart arranged alternately on either side of the ridges.

Fungicide Sprays

Sulfinette, a commercial preparation of lime sulphur with sp. gr. of 1·3, was the only fungicide used except in expt. 2. Sprays with 1 in 80–100 lime sulphur v/v plus wetter (1 in 3,000 Agral LN) were applied two and three times per season at intervals of 21 days to crops at Shambat and Zeidab respectively, starting as soon as mildews appeared. In addition to lime sulphur, Spersul (a water-dispersible powder containing 73 per cent. sulphur) and Karathane, which contains about 25 per cent. of dinitro-capryl-phenyl-crotonate, were tested in expt. 2. The concentrations of materials, given in the text, refer to active ingredients and are expressed as w/w excepting lime sulphur which is given as v/v.

Treatments were tested in a series of mainly factorial experiments in which plots and sub-plots were about $\frac{1}{10}$th and $\frac{1}{20}$th acre respectively.

1956–7 Experiments

Expt. 1, at Zeidab, tested five dates of sowing (21 and 31 October, 10, 20, and 30 November).

Expt. 2, at Zeidab, sown 4 and 5 November, tested differing concentrations of three fungicides, viz. lime sulphur, sulphur, and Karathane.

[1] R = Rebaya.

1957–8 Experiments

Expt. 3, at Zeidab, tested five dates of sowing (1 and 21 October, 10 and 30 November, and 20 December), in ten replicates arranged in duplicate 5×5 Latin squares, with each plot split for sprayed *v.* unsprayed.

Expt. 4, at Shambat, tested three dates of sowing (26 October and 11 and 26 November) ×three frequencies of spraying and unsprayed, in five replicate blocks. Sprayings were made once every one, two, or three weeks.

Expt. 5, at Shambat, tested three dates of sowing (21 October and 6 and 21 November) ×three rates of N fertilizer (112, 224, and 448 lb./acre sulphate of ammonia, 21 per cent. N) in five replicate blocks. Each plot was split for sprayed *v.* unsprayed.

1958–9 Experiments

Expt. 6, at Zeidab, tested four dates of sowing (22 and 29 October, 5 and 19 November) ×two rates of N (nil and 200 lb./acre ammonium sulphate) ×two rates of P (nil and 100 lb./acre triple superphosphate, 45 per cent. P_2O_5) ×two rates of K (nil and 80 lb./acre sulphate of potash, 49·5 per cent. K_2O) ×sprayed *v.* unsprayed. The sixty-four treatments were duplicated, and each replicate was arranged in four blocks confounding high-order interactions.

Expt. 7, at Shambat, tested two dates of sowing (6 and 22 November) ×three varieties in five replicate blocks. Each plot was split for sprayed *v.* unsprayed.

Expt. 8, at Shambat, sown 23 November, tested two seed-rates ×three varieties in five replicate blocks. Each plot was split for sprayed *v.* unsprayed.

Incidence of Mildew

The general severity of foliage disease was repeatedly assessed in all experiments, sometimes recording the same plants, using an arbitrary scale of 0 (= healthy) to 5 (= severely diseased). These indexes take into account both the leaf area covered by white mycelium and the areas which became necrotic after infection, especially by *E. umbelliferarum*. Flowers became infected but detailed records were not made.

L. taurica usually appears on the lower leaves in early December, followed 3 to 4 weeks later by *E. umbelliferarum* and *E. polygoni* which spread rapidly over the entire plant and are probably responsible for the main loss of yield [4]. Although there were considerable variations, powdery mildews were usually present about a week earlier at Zeidab, the northern site, than at Shambat.

Varying the date of sowing usually only slightly delayed the build-up of powdery mildews. In expt. 1 disease caused mainly by *E. umbelliferarum* and *E. polygoni* was more or less equally severe from mid-January onwards, for all dates of sowing (Fig. 1). Before mid-January, however, mildew caused mainly by *L. taurica* was most intense on the earliest crop, sown on 21 October. In addition to the rapid assessments of disease, the detailed estimates of the affected areas of each leaf on

randomly selected stems were made on two occasions (Table 1). The differences between the observations made on 8 and 29 January illustrate the rapid build-up of disease. In addition, the results show different

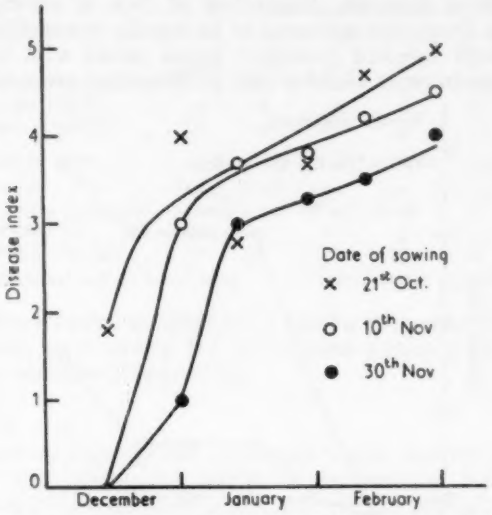

FIG. 1. Incidence of powdery mildews on broad beans sown at different dates (expt. 1, Zeidab, 1956–7).

TABLE 1. *Effect of Sowing Date on Percentage Leaf Area Affected by Bean Powdery Mildews (expt. 1, Zeidab, 1956–7)*

(*a*) *Sown 30 November 1956*	*Leaf position**							
Disease recorded on:	1–6	7 & 8	9–11	12 & 13	14–17	18	19–21	22 & 23
8 Jan. '57	>50	>20	1–10	0	..	..	..	..
29 Jan. '57	Dead	>75	>75	>75	>50	20	1–5	0

(*b*) *Sown 21 October 1956*								
Disease recorded on:	1 & 2	3–9	10–15	16–24	25	26–28	29 & 30	31 & 32
8 Jan. '57	Dead	10–20	10–20	>50	20	0–1	..	..
29 Jan. '57	Dead	25	50	>75	>75	>50	10–25	0

* Leaf 1 = lowermost leaf on main stem.

distributions of mildew on crops sown on 21 October and 30 November. The older leaves (1–15), produced before mildews were prevalent, on plants sown on 21 October, were less diseased on 8 January than the younger leaves, 16–24. Further, between 8 and 29 January mildews developed less rapidly on some of the older leaves, 3–9, than on the younger leaves, 26–28. On the latter group the area affected, mainly by *E. umbelliferarum* and *E. polygoni*, increased from 1 to at least 50 per cent.; on the former from 10–20 to only 25 per cent. Furthermore,

although leaves 26 to 28 were intensely necrotic, leaves 3–9 remained green. In contrast, none of the leaves on plants sown on 30 November appeared to resist mildew, probably because, unlike comparable leaves on earlier sowings, they did not have time to age and develop resistance before becoming infected. Regardless of date of sowing, leaves expanding after December appeared to be equally susceptible and always became severely infected (compare leaves 26–28 with leaves 12 and 13 on plants sown on 21 October and 30 November respectively).

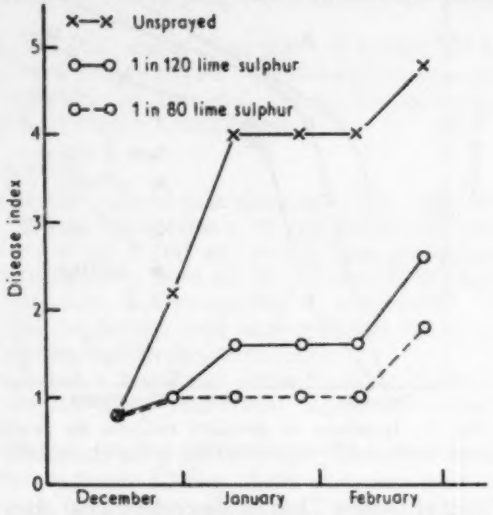

FIG. 2. Effects of lime sulphur sprays on the incidence of bean powdery mildews (expt. 2, Zeidab, 1956–7).

Apart from expt. 2, lime sulphur was the only fungicide used. Nour [4] found that it gave good control at a concentration of 1 in 100. In expt. 2 lime sulphur at 1 in 80 was slightly more effective than 1 in 120 (Fig. 2) but both greatly decreased mildew and lengthened the lives of the older leaves 1–10 (Table 2). In expt. 4 lime sulphur at 1 in 90 decreased the disease rating from 1·9 to 1·2 on 7 January and from 4·4 to 0·9 on 24 January. Spraying weekly was not significantly more effective in controlling mildews than spraying every third week.

In expt. 2, sprays with 0·18 per cent. sulphur were as effective as lime sulphur in decreasing mildew but Karathane (0·025 per cent.) was ineffective (Table 2).

Total Yields

Variety

Introduced varieties gave significantly lower yields than the local strain when tested at Shambat in expt. 7 (Table 3), even though all appeared to be equally infected. In expt. 8, however, their yields were found to depend greatly upon seed-rate. At the usual seed-rate the

TABLE 2. *Effect of Fungicide Sprays on the Incidence of Bean Powdery Mildews, Measured as Percentage Leaf Area Affected (expt. 2, Zeidab, 1956–7)*

	*Leaf position**					
I. January 1957	*1–5*	*6–10*	*11–15*	*16–20*	*21–24*	
Control . . .	Dead	>50	50	10	1	
Lime sulphur (1 in 120)	1	<1	<1	1	0	
Sulphur (0·18%)† .	5	2	2	2	0	
Karathane (0·025%) .	10	10	10	5	0	
II. 28 January 1957	*1–5*	*6–10*	*11–15*	*16–20*	*21–25*	*26–30*
Control . . .	Dead	Dead	>50	50	20–50	10
Lime sulphur (1 in 120)	<1	3	3	3	1	0
Sulphur (0·18%). .	1	5	10	5	1	0
Karathane (0·025%) .	50	35	25	10	5	1

* Leaf 1 = lowermost leaf on main stem. † Concentration of active ingredient.

yields of the three varieties tested were similar but when the seed-rate was doubled the local variety B.F.M. yielded significantly more than the introduced varieties R34 and R40.

Rates of Sowing

Doubling the usual seed-rate increased yields but the size of the effect varied with variety—e.g. yields of the varieties B.F.M. (local) and R34 (introduced) increased by 499 and 177 lb./acre (48 and 18 per cent.) respectively (Table 3).

TABLE 3. *Effect of Variety and Seed-rate on Bean Yields (lb./acre)*

	Varieties of Beans			
	B.F.M.	*R40*	*R34*	
Expt. 7		(± 31·2)		
	870	707	558	
Expt. 8		(± 50·8)		Mean (±29·3)
Usual seed-rate (1) . .	1,030	1,086	964	1,026
Double ,, (2) . .	1,529	1,374	1,141	1,348
Mean (±35·9) . .	1,279	1,229	1,052	
Difference (2–1) . .	499	288	177	

Dates of Sowing

The experiments at Zeidab usually tested a wider range of sowing dates than those at Shambat. In expt. 1 at Zeidab in 1956–7 (Table 4) the highest yield was given by beans planted on 21 October. It did not differ significantly from the yields from sowings on 31 October and 10 November, but with further delays yields decreased greatly. In 1957–8 (expt. 3, see Fig. 3) the earliest sowing was made on 1 October.

TABLE 4. *Effect of Date of Sowing on Flowering and Yields of Unsprayed* V. faba *at Zeidab (expt. 1)*

Date of sowing	*Date of first flowering*	*Yield, lb./acre*
21 Oct. 1956	22 Nov. 1956	1,648
31 Oct. ,,	10 Dec. ,,	1,392
10 Nov. ,,	14 Dec. ,,	1,416
20 Nov. ,,	20 Dec. ,,	1,097
30 Nov. ,,	8 Jan. 1957	745

L.S.D. ($P = 0.05$) = 285 lb.

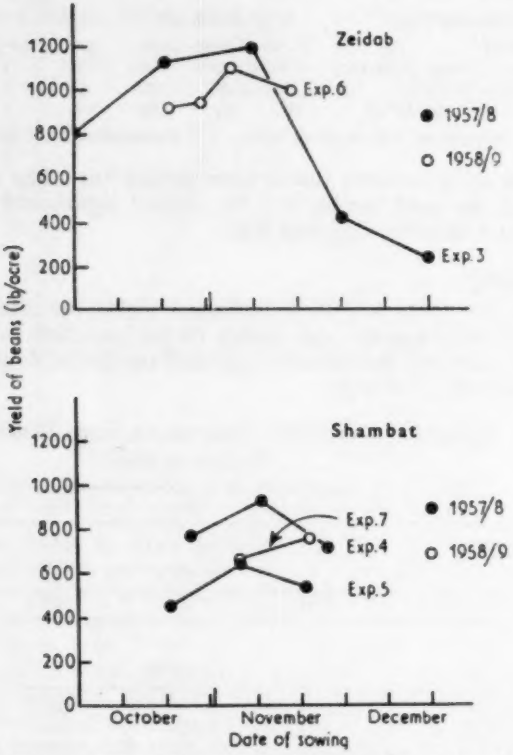

FIG. 3. Effect of date of sowing on yields of broad beans.

High yields were again given by crops sown in late October and early November and as in the previous season delaying sowing until December caused large decreases. Although beans sown early in October yielded less than those sown at the end of the month, the losses caused by planting too early were less than those suffered by delayed plantings.

Because experiments at Zeidab in the two previous seasons indicated that the optimal date of sowing was from mid-October to early November

the experiment in 1958–9 tested critically the variation within this restricted period. Beans planted on 5 November yielded significantly more than those planted on 22 and 29 October and 19 November.

The yield losses caused by delaying sowing until late November may partly be attributed to the incidence of powdery mildews. Although date of sowing did not seem to affect susceptibility of young leaves, leaves already old when mildews became widespread in January resisted infection. Not only did some of their leaves resist infection but early sown crops started to flower before mildews appeared, and pods were formed before the disease was severe (Table 4). In contrast, the entire foliage of late-sown crops was rapidly and severely infected before flowering started. The lower yields of late-sown crops probably also partly reflect losses of pods caused by flower infections.

Winter at Shambat starts later and is shorter than at Zeidab. Because broad beans sown in October at Shambat are usually severely attacked by insects, especially *Helicothrips* spp., the range of sowing dates was limited to November–December (Fig. 3). In 1957–8 (expts. 4 and 5) the highest yields were given by beans sown from 6 to 11 November and in 1958–9 crops sown on 22 November yielded significantly more than those sown on 6 November—764 against 660±25·5 lb./acre.

Fungicidal Sprays

The standard sprays of 1 in 80 to 1 in 100 lime sulphur given two or three times per season consistently increased bean yields. The increases, ranging from 86·0 to 262·0 with a mean of 172·5 lb./acre (Table 5), were associated with decreased disease.

TABLE 5. *Mean Effects of Fungicidal Sprays on Bean Yields (lb./acre)*

(a) Lime sulphur sprayed two or three times per season

1957–8	*Unsprayed* (1)	*Sprayed* (2)	*Diff.* (2–1)	*S.E. of diff.*
Expt. 3, Zeidab . .	669·0	841·0	+172·0	±17·7
,, 4, Shambat . .	712·0	902·0	+190·0	±42·9
,, 5, Shambat . .	477·0	604·0	+127·0	±12·7
1958–9				
Expt. 6, Zeidab . .	946·0	1,032·0	+ 86·0	±41·1
,, 7, Shambat . .	613·0	811·0	+198·0	±25·4
,, 8, Shambat . .	1,056·0	1,318·0	+262·0	±41·3

(b) Comparison of different materials (expt. 2, Zeidab, 1956–7)

	Lime sulphur		*Sulphur*		
Unsprayed	*1 in 120*	*1 in 80*	*0·18%*	*0·7%*	*Karathane 0·025%*
1,073	1,610	1,516	1,558	1,486	1,324

L.S.D. ($P = 0·05$) = 261 lb.

Increasing the frequency of spraying from once every 3 weeks to weekly did not further decrease the incidence of mildew or significantly increase yield. Spraying once every 1, 2, and 3 weeks increased bean yields from 712 in the unsprayed controls to 876, 917, and 916±30·4 lb./acre respectively.

Spraying usually had the greatest effect with crops sown at the optimal date (Table 6). In both expts. 5 and 6, at different sites in different

TABLE 6. *Effects of Lime Sulphur Sprays on Yields (lb./acre) of Beans sown on Different Dates*

Expt. 5, Shambat, 1957–8

	Dates of sowing		
	21 Oct.	*6 Nov.*	*21 Nov.*
Unsprayed (1) .	421	538	472
Sprayed (2) . .	478	736	599
Difference (2–1) .	+57	+198	+127

S.E. for horizontal and diagonal comparisons = ±36·8.
S.E. for vertical comparisons = ±15·6.

Expt. 6, Zeidab, 1958–9

	22 Oct.	*29 Oct.*	*5 Nov.*	*19 Nov.*
Unsprayed (1) .	942	889	1,007	946
Sprayed (2) . .	905	992	1,189	1,044
Difference (2–1) .	−37	+103	+182	+98

S.E. = ±54·8.

seasons, spraying increased yields of *V. faba* planted on 5 and 6 November, the optimal dates, by at least 180 lb./acre. In mid-October and mid-November the mean effects were +10 and +113 lb./acre respectively.

Table 5 shows that the protection given by sulphur sprays was reflected in yield increases comparable with those given by lime sulphur. Varying the concentrations of lime sulphur and sulphur sprays within the ranges of 1 in 80 to 1 in 120, and 0·18 to 0·7 per cent. respectively, did not affect the yield responses. Karathane, which gave less protection than sulphur sprays, increased yields but not significantly.

Fertilizers

Nitrogen was the only nutrient that significantly affected mean yields in expt. 6; an increase from 907 to 1,072 lb./acre (Table 7). Although phosphorus alone did not affect mean yields, its interaction with the other nutrients was significant. In the absence of potassium, phosphorus had no effect, but together they increased yields to about the same level as nitrogen alone. In contrast, phosphorus had no effect on crops

receiving nitrogen, although in its absence the addition of phosphorus increased yields.

The effects of nitrogen and phosphorus were also influenced by spraying and by dates of sowing (Table 8). Nitrogen, unlike spraying, had least effect on crops sown at the optimal date. Crops sown on 5 November yielded 1,069 lb. of beans per acre without nitrogen and only 58 lb. more with it, whereas those sown on 22 October and 19 November

TABLE 7. *Effects of* N, P, *and* K *Fertilizers on Bean Yields (expt. 6, Zeidab, 1958–9)*

Yields of Beans, lb./acre

$\pm 38{\cdot}7$

	No N	N	*No* P	P	*Mean* ($\pm 27{\cdot}4$)
No K	864	1,046	960	950	955
K	949	1,097	960	1,086	1,023
No N			841	972	907
N			1,079	1,065	1,072
Mean ($\pm 27{\cdot}4$)			960	1,018	

gave a response of 240 lb./acre to nitrogen. On sprayed crops nitrogen increased yields per acre by 205 lb. and on unsprayed beans by only 125 lb. Similarly, increasing the dressing of ammonium sulphate from 112 to 448 lb./acre in expt. 5 increased yields of sprayed crops by 18·1 per cent. and of unsprayed crops by only 6·5 per cent. (Table 8). In contrast, phosphorus increased yields of unsprayed more than of sprayed crops. The yields of unsprayed beans without phosphorus were increased from 880 to about 1,025 lb./acre either by spraying or by adding phosphorus, suggesting that this nutrient increases the tolerance of beans to powdery mildews. No further increase was gained by giving both treatments together (Table 8).

Components of Yield

The variations in yield were usually attributable to changes in the numbers of pods. In expts. 4, 5, and 7, at Shambat, none of the treatments affected the weights of 100 beans, but in expt. 6 they varied from 37·9 to 40·7, 41·1, and $39{\cdot}0 \pm 0{\cdot}4$ in crops sown on 22 and 29 October, 5 and 19 November respectively. In contrast, nitrogen spraying, and date of sowing, all affected the number of pods. Nitrogen increased the pod number from 100 to $114 \pm 2{\cdot}8$ per metre of row and spraying from 101 to 113. The numbers were respectively 103, 99, 114, and $112 \pm 3{\cdot}9$ for sowings on the above dates. In expt. 3, lime sulphur increased numbers from 104 to 134/metre while plants sown on 1 and 21 October, 10 and 30 November, and 20 December gave respectively 114, 152, 161, 136, and 25 pods/metre of row.

TABLE 8. *Effects of* N *and* P *on the Yields (lb./acre) of Sprayed and Unsprayed Beans sown on Different Dates*

A. *N × spraying*

Expt. 5, Shambat, 1957–8

	Ammonium sulphate/acre				
	112 lb. (1)	*224 lb.*	*448 lb.* (2)	*Mean* (±9·0)	*Increase* (2–1)
Unsprayed . .	462	476	492	477	30
Sprayed . .	557	598	658	604	101
Mean (±35·1) . .	509	537	575		

S.E. for horizontal and diagonal comparisons ±36·8.
S.E. for vertical comparisons ±15·6.

Expt. 6, Zeidab, 1958–9

	±38·7			
	No N (1)	N (2)	*Mean* (±27·4)	*Diff.* (2–1)
Unsprayed . .	883	1,008	946	+125
Sprayed . . .	930	1,135	1,032	+205
Mean (±27·4) . .	907	1,072		

B. *P × Spraying (expt. 6)*

	±38·7			
	No P (1)	P (2)	*Mean* (±27·4)	*Diff.* (2–1)
Unsprayed . .	879	1,012	946	+133
Sprayed . . .	1,040	1,024	1,032	—16
Mean (±27·4) . .	960	1,018		

C. *N × Dates of sowing (expt. 6)*

	Dates of sowing			
	22 Oct.	*29 Oct.*	*5 Nov.*	*19 Nov.*
	±54·8			
No N (1) . .	800	884	1,069	874
N (2) . .	1,047	997	1,127	1,116
Diff. (2–1) . .	+247	+113	+58	+242

Discussion

The optimal date of sowing of winter beans in northern Sudan is affected by the incidences of pests and diseases. Powdery mildews appear earlier at Zeidab than at Shambat, but they rarely became general at either site until January. In the interval between sowing (October–December) and early January, beans are little affected by diseases and early sown crops develop further than late-sown crops,

forming pods before powdery mildews become widespread. Not only do early sown crops remain disease-free for longer than late-sown crops but their older leaves are also resistant to infection. In two of the three experiments at Shambat, crops sown in early November gave the largest yields. Earlier sowings tended to be seriously damaged by insects, especially *Helicothrips* spp. At Zeidab, where beans are traditionally sown in mid-November and where the winter starts earlier, high yields were given by crops sown over a period starting earlier and extending longer than at Shambat—from mid-October to early November. Because yields drop very rapidly when sowing is delayed after mid-November, the sowing date at Zeidab could with advantage be brought forward to the beginning of the month when small variations in the date of sowing have only minor effects on yield.

The lack of phosphorus [10, 11] and of potassium [12, 13] sometimes increases the severity of disease caused by *Botrytis fabae* Sardiña. In the present experiments the disease assessments were not critical enough to detect effects of fertilizers on disease incidence, even if they were present. The bean yields, however, indicate that plants with nitrogen and phosphorus were affected differently. Adding the latter increased yields to the same extent as spraying with lime sulphur and no further increase was gained by giving both treatments. The yield increases after adding nitrogen were at least twice as great on sprayed as on unsprayed crops.

Lime sulphur sprays (these also control *Uromyces fabae* (Pers.) de Bary [14], which sometimes occurs [3] but was not observed in these experiments) consistently decreased the incidence of powdery mildews and increased yields by 23 per cent. The lower yields given by the unsprayed and heavily infected crops reflect the killing effect of flower infections and the inability of infected plants, with smaller effective leaf areas, to maintain as many pods as sprayed plants. The increases varied with dates of sowing and were largest on crops planted at the optimal date. In contrast, yield increases given by nitrogen were largest on crops sown under conditions other than optimum and consequently the variations caused by differing dates of sowing were decreased.

In temperate zones, bean yields are often increased by adding either phosphorus or potassium but rarely by nitrogen [15]. In expt. 6, however, phosphorus and potassium separately had no effect, whereas nitrogen significantly increased yields. This increase probably occurred because of the poor development of root nodules. The strain of Rhizobium which produces effective nodules on *V. faba* is comparatively rare in the tropics [16]. If nodules on *V. faba* persist until fruiting, unlike those on other legumes in Northern Sudan [17], yields could perhaps be greatly improved by planting *V. faba* repeatedly on the same sites to increase the soil populations of the effective strain of Rhizobium. However, because phosphorus and potassium together significantly increased yields, the conditions were possibly unfavourable for nitrogen fixation by the existing populations of Rhizobium. In his review, van Schreven [18] noted similar effects on other legumes where

nitrogen fixation is stimulated by potassium only in the presence of phosphorus.

In these experiments, fertilizers, spraying, and dates of sowing affected yields mainly by altering the numbers of pods per plant. Similarly, Hodgson and Blackman [19] found that varying the seed-rate of *V. faba* affected the numbers of pods per plant but that the weights of 100 seeds remained unchanged. *V. faba* produces fewer pods per plant in dense crops than in sparse crops and consequently yields over a wide range of seed-rates tend to remain constant. The 48 per cent. increase obtained by doubling the usual seed-rate of the local strain at Shambat suggests, however, that the seed-rate used by the local cultivators is too low.

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(Received 29 December 1959)

MANURING OF COTTON IN WEST PAKISTAN[1]
V. EFFECT OF NITROGEN, PHOSPHORUS, AND POTASSIUM, ALONE AND IN COMBINATION, ON THE YIELD OF SEED COTTON

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Summary

Experiments were laid out at five localities, using nitrogen, phosphorus, and potassium fertilizer separately and together. Nitrogen was used at the rate of 50 lb. N per acre. The responses to these treatments were varied due to differences in varieties and soils. The treatments which generally resulted in highest yields at Lyallpur, Wazirkot, Montgomery, and Khanewal were NP, NPK, NP, and P respectively. Results from Multan were inconclusive. The results indicated the general need of phosphorus for cotton. However, the use of phosphorus fertilizers at the present level of prices for the produce and the fertilizer was uneconomical.

PREVIOUS work on the effects of nitrogen, phosphorus, and potassium fertilizers on cotton in India and Pakistan has been reviewed by Dastur [1], Panse [2], Stewart [3], and Vaidyanathan [4]. In general, nitrogen alone, or together with phosphorus or potassium or both, increased the yield of seed cotton; in absence of nitrogen, phosphorus alone or with potassium did not improve yields, while potassium applied alone sometimes depressed them. The response to nitrogen was suppressed by salinity in the soil or subsoil.

The need for nitrogen in this cotton-growing area is general. Soil analyses and field trials have also indicated the need for phosphorus and potassium in certain localities; but in the canal colonies favourable responses to them had not been obtained. This might have been due to incorrect time or method of application. A study of the effects of phosphorus and potassium, alone and in combination with nitrogen, on the yield of seed cotton in this area was therefore undertaken.

Materials and Methods

Experiments were conducted for three years (1954–5, 1955–6, 1956–7) at five stations, using cotton varieties L.S.S., 238F, and 124F (see Part I of the Series [5]). The experiments were laid out in randomized blocks, with six replicates. The plot size was 1/40 acre. Besides the control, there were seven fertilizer treatments: N, P, K, NP, NK, PK, and NPK. The fertilizers were applied at the rates of 50 lb. N, 62·5 lb. P_2O_5, and 50 lb. K_2O per acre, in the form of ammonium sulphate, single superphosphate, and potassium sulphate. The superphosphate

[1] Publication of the Department of Agriculture, West Pakistan. The scheme was partially financed by the Pakistan Central Cotton Committee, Karachi.

TABLE 1. *Mean Yields of Seed Cotton (maunds per acre)*

L = Lyallpur. W = Wazirkot. Mo = Montgomery. K = Khanewal. Mu = Multan. One maund = 82 lb.

	1954–5					*1955–6*					*1956–7*					*Three-year averages*				
Treatments	L	W	Mo	K	Mu	L	W	Mo	K	Mu	L	W	Mo	K	Mu	L	W	Mo	K	Mu
N . .	17·4	10·7	32·3	17·8	15·9	11·6	17·4	12·4	13·4	17·5	11·1	14·1	8·0	13·3	7·6	13·4	14·1	17·5	14·8	13·7
P . .	18·1	11·6	31·4	19·1	14·9	10·4	15·1	13·6	20·8	17·8	14·1	14·1	7·7	14·5	7·7	14·2	13·6	17·5	18·1	13·4
K . .	17·7	10·1	29·9	17·8	13·1	10·3	15·2	13·4	13·9	15·9	12·5	9·7	8·6	14·0	6·2	13·5	11·7	17·3	15·2	11·8
NP . .	18·4	10·4	34·9	17·5	15·7	12·3	17·8	13·9	14·9	16·6	13·3	13·7	8·9	13·8	7·6	14·7	14·0	19·2	14·4	13·3
NK. .	18·0	10·8	28·4	19·0	14·1	12·9	18·4	14·0	13·7	16·9	14·9	12·5	8·4	13·6	7·2	15·3	13·9	16·9	15·5	12·7
PK . .	17·8	11·2	29·2	17·2	14·0	10·9	14·1	12·9	14·7	18·4	14·0	12·6	7·5	13·7	7·4	14·0	12·7	16·5	19·2	13·3
NPK .	17·5	11·0	33·1	16·7	16·6	12·4	16·5	14·7	15·1	16·6	15·4	15·5	8·7	15·2	7·6	15·1	14·3	18·8	15·7	13·3
Control .	16·1	11·0	28·6	17·4	13·4	10·5	15·9	12·3	14·2	18·4	14·5	8·5	8·1	13·4	8·3	13·7	11·8	16·3	15·0	13·4

and potassium sulphate were applied in furrows and covered with soil, three to four weeks before sowing. Ammonium sulphate was applied in a single broadcast between the cotton rows at a preflowering stage, and followed by an irrigation. Other operations were normal, i.e. cotton followed wheat, row-to-row distance was 2½ feet, and five to seven 3-inch irrigations were given, depending on the rainfall, in addition to one 4-inch irrigation for seedbed preparation.

Results and Discussion

The mean yields at each of the five stations, for each year, and the averages for the three-year period, are given in Table 1.

The results of statistical examination of these data by the analysis of variance are summarized in Table 2.

TABLE 2. *Minimum Significant Differences in Mean Yields*

Stations	*Years*			*Pooled analysis*	
	1954–5	*1955–6*	*1956–7*	*Fertilizers*	*Years*
Lyallpur .	N.S.	N.S.	1·95•	N.S.	0·89†
Wazirkot .	N.S.	2·56•	3·00•	1·49†	0·89†
Montgomery .	3·60†	N.S.	N.S.	1·47†	0·89†
Khanewal .	N.S.	N.S.	N.S.	N.S.	0·87†
Multan . .	N.S.	N.S.	N.S.	N.S.	0·73†

N.S. = non-significant. • = significant at $P = 0{\cdot}05$. † = significant at $P = 0{\cdot}01$.

For individual years the differences are mostly non-significant, except at Wazirkot where they were non-significant in one year only. The pooled analysis for years shows highly significant differences at all stations. The non-significance of differences in fertilizer effects was thus due to variations in various factors affecting the yields of cotton.

These data show that in some years the yields have been below normal. This was due to the incidence of tirak (premature opening of bolls), root-rot, pest and insect attacks, and scarcity of water due to canal closures on account of floods. Closer examination of the data, on the basis of the number of times the yield from a particular treatment occupies the first, second, and the third positions shows that in spite of adverse conditions, the treatments which resulted in highest yields at Lyallpur, Wazirkot, Montgomery, and Khanewal were NP, NPK, NP, and P, respectively. The results from Multan are inconclusive. In general, treatments NK and NPK have given similar but highest yields, while treatment NP follows next. At Wazirkot, these treatments resulted in highest yields, though their order at this station is changed to NPK, NP, and NK. At Montgomery, NP and NPK gave best yields, while N and P were bracketed in the third place. At Khanewal PK resulted in highest yields, followed by P and NPK. These results definitely indicate the necessity for the use of phosphorus along with nitrogen generally, and of potash in a complete fertilizer for cotton.

The responses in yields of seed cotton from the use of fertilizers are given in Table 3.

The increased yields at all the stations except Multan, for some of the treatments, seem to be quite attractive; but it is important to know whether such treatments are economic. The calculated profits or losses for the fertilizer treatments are presented in Table 4.

These figures have been worked out by rating ammonium sulphate (20% N), superphosphate (16% P_2O_5), and potassium sulphate (48% K_2O) at Rupees[1] 5·9 (controlled price), 11·2 (factory price at Lyallpur), and 12·8 (price in the United States [6]) per maund, respectively, and seed cotton at Rupees 30 per maund.

TABLE 3. *Yield Responses to Fertilizers (Differences between Fertilizer Treatments and Control), in maunds per acre of Seed Cotton*

Treatments	Responses				
	Lyallpur	*Wazirkot*	*Montgomery*	*Khanewal*	*Multan*
N . .	−0·36	+2·29	+1·20	−0·19	+0·27
P . .	+0·48	+1·85	+1·20	+3·13	+0·06
K . .	−0·20	−0·10	+0·90	+0·23	−1·63
NP . .	+0·93	+2·20	+2·97	−0·64	−0·10
NK . .	+1·56	+2·12	+0·59	+0·44	−0·65
PK . .	+0·25	+0·94	+0·19	+4·18	−0·10
NPK . .	+1·48	+2·56	+2·44	+0·66	−0·10

TABLE 4. *Calculated Profits and Losses in Rupees per acre for Increased Yields of Seed Cotton*

Treatments	Stations				
	Lyallpur	*Wazirkot*	*Montgomery*	*Khanewal*	*Multan*
N . .	−28·76	50·74	18·04	−23·66	−9·86
P . .	−38·85	2·25	−17·25	40·65	−53·07
K . .	−22·25	−19·25	10·75	−9·35	−65·15
NP . .	−43·31	−5·21	14·89	−90·41	−74·21
NK . .	12·59	29·39	−16·51	−21·01	−53·71
PK . .	−62·00	−41·30	−63·80	55·90	−72·50
NPK . .	−43·06	−10·66	−14·26	−67·66	−90·46

These data show that, in spite of the increased yields from the application of potassium and phosphorus with nitrogen, it was not profitable to use potassium and phosphorus at the above prices of the produce and the fertilizers, although the data in Table 3 indicate a need for these nutrients, especially phosphorus.

At Lyallpur, Wazirkot, and Montgomery complete fertilizer (NPK) gave good results; but at Khanewal potassium and phosphorus reacted favourably even without nitrogen, indicating that at that station these nutrients may be limiting factors. To verify this, soil samples were taken, not only from the experimental plots but from other parts of the farm as well. Soil samples were taken from the surface 9 inches, and analysed for 'available' phosphorus using the bicarbonate method of Oslen *et al.* [7]. The results are given in Table 5.

[1] One rupee is equivalent to $0·21 or 1s. 6*d*.

The limits established in these laboratories for soils which will respond to the application of phosphorus, or which will probably respond, or which will not respond, are 0–4, 4–8, and above 8 p.p.m. phosphorus respectively. If the data for yields of seed cotton at Khanewal (Table 1) are compared with the quantities of available phosphorus at the experimental sites (Table 5) it will be observed that on the above basis phosphorus is sufficient at two sites, while at the

TABLE 5. *'Available' Phosphorus in Khanewal Soils*

Description of soil	*Phosphorus, in p.p.m. air dry soil*
Experimental area	10·74
" "	11·88
" "	6·00
" "	5·40
Other parts of the farm. Heavy soil	3·12
" " " "	6·16
" " Medium soil	8·30
" " " "	9·94
" " Light soil	4·60
" " " "	3·72

other two there is probability of response to the phosphorus applications. Table 5 also shows that whereas medium soils are not likely to respond to the application of phosphorus, the heavy and the light soils may be expected to respond. However, in these experiments the heavy soils did not respond to superphosphate. In these soils the phosphorus may be present as calcium triphosphate and may become available through root action although it is not extracted in the laboratory by the analytical method used [7].

Unpublished records show that crops responded to superphosphate in the mountainous and the sub-mountainous tracts where average annual rainfall ranges from 30 to 50 inches, whereas in the canal-colony areas only legumes responded to superphosphate. Wahhab and Bokhari [8] assessed soils from various tracts by biological methods and field trials. They found that besides the soils of the mountainous and the sub-mountainous tracts mentioned above, light soils of the canal-colony areas are also deficient in available phosphorus.

In general it may be concluded that there is a need for the use of phosphorus fertilizers on cotton but the main impediment to their use is the cost of the fertilizers in relation to the prices realized for the produce.

Acknowledgements. The authors are grateful to Dr. D. M. Qureshi, Statistician, Lyallpur, for statistical analysis of the data.

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(Received 26 August 1958; revised July 1960)

THE DISEASES OF GROUNDNUTS IN NORTHERN RHODESIA

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Summary

An account of the diseases which have been recorded on the groundnut crop in Northern Rhodesia is presented, together with control measures that have been found effective. The most important diseases are the rosette virus and leafspot, which can generally be controlled satisfactorily by cultural methods. Other less important diseases are also described.

THE groundnut is an important crop in African agricultural systems in Northern Rhodesia. It is the most widely grown grain legume and is found in subsistence cultivation throughout the Territory. Climatically Northern Rhodesia is suitable for groundnut production, though soil conditions in some areas do not favour the crop. Compacting soils of poor drainage, and soils leached of essential elements, present special problems. There are, however, some very good groundnut soils in the Territory; those of the Eastern Province are among the best. Production in this area exceeds requirements and a small but valuable export trade has developed.

Several diseases have been recorded on the local groundnut crop [1]. Most are of minor importance and sporadic occurrence. Experience has shown that disease problems are encountered in their most severe form when attempts are made to grow the crop in unsuitable conditions.

Rosette Disease

The most serious groundnut diseases in Northern Rhodesia are rosette and leafspot. Rosette is produced by an aphid-transmitted virus. There appear to be three types of disease symptoms produced locally by viruses in groundnuts, namely:

1. Stunting of the plant without chlorosis and distortion of the leaflets —green rosette.
2. Mottling of the leaflets with some distortion and stunting—mosaic.
3. Stunting of the plant with severe chlorosis and distortion of leaflets —yellow rosette.

Yellow rosette is by far the most serious disease of this group, and given favourable conditions it spreads rapidly. The degree of stunting depends on the stage of growth at which infection takes place. The earlier in the season that this occurs the more serious is the stunting. Infection may take place soon after emergence, and diseased plants may be recorded within a few weeks of planting. Secondary spread, varying in extent according to the prevailing conditions, may occur from such primary infections. The maximum extent of the disease is reached three months after emergence, when under local conditions the peak of vegetative growth has been reached.

[Empire Journ. of Exper. Agric., Vol. 29, No. 113, 1961.]

In the earlier part of the season it is usually possible to observe different types of virus infection. As the season progresses yellow rosette spreads and becomes the dominant form, the others becoming less apparent as they do not usually spread to the same extent. Losses caused by the groundnut viruses in Northern Rhodesia are due almost entirely to yellow rosette.

Rosette has been known to occur in Northern Rhodesia for many years. The disease was first recorded in serious proportions at the Pilot Groundnut Scheme at Mukulaikwa in the Central Province. Large-scale experimental plantings of the variety Natal Common were made from 1950 to 1954. In the first season the incidence of rosette was not high. In the succeeding seasons the disease became serious, infection eventually reaching the 100 per cent. level. 'Volunteer' groundnuts, held to be largely responsible for disease carry-over, could be found in numbers which depended on conditions at harvest. More could be found after wet weather at harvest time than when it had been dry. Conditions did not usually favour the occurrence of high populations of 'volunteers', but sufficient may have occurred to be important in carrying over disease. Genera of leguminous plants known to be alternate hosts of the groundnut aphis in Tanganyika occur locally [2], examples being Vigna, Lonchocarpus, and Brachystegia. Although means of disease carry-over have not as yet received detailed attention in Northern Rhodesia, there are grounds for presuming that the methods of carry-over in Tanganyika and Northern Rhodesia are generally similar, although differing in detail.

Evans at Nachingwea [2, 3] discovered resistance to rosette in the Mwitunde group of varieties under field conditions. An importation of a Mwitunde strain was made in late 1954 with a view to assessing its rosette resistance under field conditions at Mukulaikwa. This was planted in a 1-acre plot for the purpose of comparison with a plot of similar size planted to Natal Common. Estimates of the proportion of rosette-infected plants were made during the growing season. In an actual count of rosetted plants in the Mwitunde plot shortly before harvest, 842 infected plants were recorded, which represents an infection level of about 2 per cent. It was not possible to count the numbers of Natal Common plants infected at the same stage because of extensive defoliation caused by Cercospora leafspot; estimates of infection levels, made before defoliation started, put the level of infection at 100 per cent. Comparatively few aphids were present in the Mwitunde plot and no large colonies were found, in contrast to the Natal Common plot where aphids were abundant and formed large colonies. The comparison between the two plots provided striking visual evidence of the rosette resistance of the variety Mwitunde.

Complementary to this empirical study of field resistance to rosette were variety yield trials laid down at Mukulaikwa in the seasons 1954–5 and 1955–6. Yields of all varieties grown were disappointingly low. Those of Natal Common were the lowest at 100 and 40 lb. of kernels per acre respectively in the two seasons. Comparable yields of Mwitunde were 261 and 223 lb. per acre. These yields were significantly higher than those of Natal Common at the $P = 0{\cdot}001$ and $0{\cdot}01$ levels respectively

for the two seasons. The very low yields of all varieties, including Mwitunde, at this Station gave a clear indication that factors other than diseases were preventing economic yields being obtained. One probable cause was the nature of the soil. Mukulaikwa soil, although sandy, has a high clay content, and has the property of compacting and setting hard on drying; when moist it is worked easily, but when dry it can only be worked with difficulty. In addition, there is pan formation at a depth of about 3 feet, with resultant impeded drainage. It is believed that poor drainage may have been an important factor in causing low yields and also in rendering the groundnut crops grown there so extraordinarily susceptible to rosette.

Fortunately the position at Mukulaikwa in the years 1950–6 is not typical of the Territory as a whole. African cultivators usually attempt to avoid unsuitable soils for groundnut cultivation. The groundnut is a crop with high labour requirements, and Africans individually do not cultivate very large acreages. Groundnut gardens tend to be small and dispersed over a large area, with other crops and natural vegetation intervening, with the result that extensive build-up of aphid and virus infection potential does not often occur. The strains grown by Africans are predominantly forms with seed dormancy. 'Volunteer' groundnuts usually do not appear until the following rains in the succeeding crop; the African cultivator is often reluctant to destroy them.

Severe rosette infections are found most frequently in poor stands of groundnuts, or crops which have been planted late. The effect of these factors singly or in combination varies in different regions. In parts of the Central Province late planting may result in extremely high infections, which can be avoided almost completely by early planting. In other areas rosette may occur with late planting, but for reasons not yet apparent, little or no spread of the disease takes place. A similar situation occurs with regard to good and bad stands. The spread of rosette depends to a considerable extent on very local conditions. The recommended practices of early planting, and high plant populations, aimed at producing a complete plant cover, have additional agronomic advantages. In groundnuts early plantings outyield later-sown crops. At high plant populations the most efficient use can be made of the soil. Plant populations of 40,000–50,000 per acre, uniformly spaced, can be carried even in the drier parts of the country if planted early.

At the present time severe outbreaks of rosette can be most readily ascribed to shortcomings in husbandry practices in many instances. It is surprising that serious outbreaks are not more common. The usual pattern of infection takes the form of irregular patches of infected plants among which one or more very stunted plants may be found, the probable primary infections.

Evans [2] points out the shortcomings of orthodox small-plot experiments in assessing varietal resistance to rosette. In Northern Rhodesia the only reliable indication of varietal rosette resistance so far given has been at Mukulaikwa with very large plots. Introduction plots, and plots in variety trials, have given no consistent guide in this respect.

In the trials at Nachingwea it was observed that Mwitunde was

susceptible to the rosette virus, the symptoms differing from the typical forms. The behaviour of aphids differed on Mwitunde and Natal Common, a high reproductive rate being observed on the latter variety. Since Mwitunde appears to be a relatively unsuitable host for the groundnut aphis it is perhaps permissible to regard the field resistance of this variety to rosette as aphid resistance. Field observations confirm that Mwitunde supports lower aphid populations than Natal Common in Northern Rhodesia just as it does in Tanganyika.

Cercospora Leafspots

A disease causing more consistent and widespread damage is leafspot. Two species of fungi have been observed causing the typical leafspot lesions, *Cercospora personata* (Berk. and Curt.) Ell. and Ev. and *C. arachidicola* Hori. Both species have been found in Northern Rhodesia. It is possible to distinguish these species visually in the field. The conidiophores of *C. personata* are grouped together on the lower surface and are apparent as evenly spaced minute black spots on the lesions; those of *C. arachidicola* occurred in loose tufts which are not readily visible. Both fungi have very similar effects, and small brown, circular lesions are produced which may have a yellow halo. Lesions caused by *C. personata* tend to be darker in colour than those caused by *C. arachidicola*. Single lesions have been recorded up to a centimetre in diameter.

Several lesions may occur on a single leaflet, and in susceptible varieties leaflets die as a result and are shed. In the latter part of the season stems and petioles are attacked by the same fungi and show elongated oval or irregular lesions of a dark brown colour. At harvest a very susceptible variety may be completely defoliated by a heavy attack of leafspot.

Three main methods of controlling leafspot have been used [4, 5], namely crop rotation, the use of resistant varieties, and fungicide treatments. Observations in Northern Rhodesia suggest that by planned crop rotation satisfactory control of leafspot may be achieved. The effectiveness of control is influenced by the distance between sites of successive crops and the direction of prevailing winds. Local crops surrounded by natural windbreaks have been observed to be substantially free of the disease quite late in the season. A similar effect has been suggested by Jaubert in Senegal [6].

Debris of the preceding crop is reported to be the primary source of inoculum for subsequent infections [7]. With the onset of favourable conditions perithecia are formed (though these have not yet been found in Northern Rhodesia), and with the formation of asci and ascospores infection of groundnut plants in the vicinity can take place. Self-sown plants inevitably occur as it is impossible not to leave some pods in the field. Destruction of 'volunteer' plants would assist control but in practice this may not always be possible. The African farmer is reluctant to destroy 'volunteer' groundnuts. Secondary spread of the disease by means of conidia takes place through wind action [8]. It appears to be almost impossible to avoid leafspot in large-scale cultivation, and any area open to the wind receives inoculum sooner or later. Spore dispersal

is very efficient and crops grown in areas some distance from any previous known groundnut cultivation become infected eventually.

The use of resistant varieties is an obvious method of controlling leafspot. Some varieties show reasonably high degrees of resistance but no immune varieties have been found so far. Resistance to leafspot is correlated with branching habit. Bunting [9] separates the groundnuts into sequentially branched and alternately branched forms. Observation on a large variety collection in Northern Rhodesia has shown that sequentially branched varieties are almost invariably susceptible to leafspot, a single exception being noted. Alternately branched varieties show a greater degree of resistance. Hemingway in Tanganyika [5, 10, 11] has studied this resistance and reports differences of degree in the leafspot resistance of the alternately branched forms he studied. Resistance to leafspot as measured by retention of leaflets shows a very similar variation in Northern Rhodesia. An exceptional case of a highly susceptible alternately branched variety has been recorded in the variety collection, in a selection of Georgia Bunch 207–3–24–1. On the other hand, the Manyema type SA43–G909 is sequentially branched but shows leafspot resistance equal to that of some alternately branched forms. Hemingway [5] relates colour and thickness of leaf, and size of stomatal pore, to leafspot resistance. It is interesting to observe that the susceptible Georgia Bunch variety has a leaf similar in colour to that of Spanish varieties while the resistant Manyema has a leaf of the same colour as that of the majority of alternately branched forms. Although the past history and origins of these forms are not known it seems not unlikely that they may be hybrids between alternately and sequentially branched parents.

The local strains grown by African cultivators are fairly resistant to leafspot and are alternately branched. The introduced strains Natal Common and Virginia Bunch (i.e. Valencia Bunch) belonging to the sequentially branched group are very susceptible to leafspot damage. It is interesting to note that Mwitunde and the other reputedly rosette-resistant varieties show alternate branching and are also resistant to leafspot. A reasonable degree of leafspot control is achieved in local farming systems in which successive groundnut crops are not taken, and resistant varieties are used. If early destruction of 'volunteers' was also practised the position would probably be better still. When introduced susceptible varieties are used, considerable loss of value of the crop may result from two causes: the haulm when cured for hay will be devoid of leaf and much lower in feeding value than otherwise; and a reduced yield of kernels, which may be appreciably lower in quality, can be expected as a result of a severe attack.

The use of the introduced leafspot-susceptible variety Natal Common at the experimental large-scale plantings from 1950 to 1954 at Mukulaikwa focused attention on this disease as well as on rosette. As with rosette, no trouble from leafspot was experienced in the first season. In the second and succeeding seasons the crop was very severely attacked and completely defoliated 6 weeks before the expected date of harvest (i.e. after about 80 days, early maturing varieties requiring 110–20 days to mature). The problem of 'volunteers' at Mukulaikwa and elsewhere

seems to be a very pertinent one with respect to leafspot. The 'volunteer' crop emerging soon after the first rains very soon becomes heavily infected with leafspot, and provides considerable quantities of inoculum for spread of the disease. The closer the siting of successive crops, the sooner will infection take place, having regard to the direction of prevailing winds.

The use of fungicides in controlling leafspot has been investigated. Experimental work is as yet in an early stage, but there are strong indications that a satisfactory measure of control can be achieved by a range of fungicides. Materials that have been used in trials to date are the following: Bordeaux mixture, sulphur dust, Zineb, and Maneb (commercial preparations containing zinc and manganese respectively). These four materials are effective in controlling leafspot, the ultimate choice depending on the cost of the material itself and the machinery to apply it.

In the first year of trials no effects of the treatments applied were observed, principally because of an unusually low incidence of leafspot in the area of the trial. The experiment was repeated in the following two seasons 1957–9. The variety used was a brown Manyema type which was known to be susceptible to leafspot. The sites chosen were adjacent to those of the preceding season's groundnut crop, with the object of obtaining a really high inoculum potential. This objective was achieved, and the control plots and guard rows were very heavily attacked. The leaves of control plants became yellowish green in colour, contrasting with the much darker green of plants in the treated plots. At harvest time plants in the control plots had shed most of their leaves, in treated plots retention of leaves was very much better. The spray treatments were applied successfully in both seasons. The sulphur-dust treatment in the 1957–8 season has been less effective, due perhaps to a sub-optimal rate of application. The results of these trials are presented in Table 1.

TABLE 1. *Leafspot Control Trials with Fungicides. Yields of Kernels, lb./acre*

		Treatments					
		Bordeaux mixture	*Zineb*	*Maneb*	*Sulphur dust*	*Control*	*General mean*
1957–8	Treatment means	1,566	1,391	1,399	961	657	1,193
C.V. 17·3%. Least significant differences: 286 at $P = 0{\cdot}05$; 401 at $P = 0{\cdot}01$; 567 at $P = 0{\cdot}001$							
1958–9	Treatment means	2,235	2,248	2,227	2,105	1,486	2,060
C.V. 14·6%. Least significant differences: 311 at $P = 0{\cdot}05$; 442 at $P = 0{\cdot}01$; 625 at $P = 0{\cdot}001$							

In 1957–8 the spray treatments produced double the control yield, in 1958–9 the increase was approximately 50 per cent. The earlier of the two seasons was not a good one for groundnuts. The rains were rather late and planting was not possible before mid-December. In the second season planting took place in late November; in this season conditions

generally were much more favourable and this is reflected in the higher yields produced. It is noteworthy in this connexion that the depression of yield produced by leafspot was also rather less severe than in the previous season.

The magnitude of yield depressions brought about by the leafspot diseases is such as to justify serious consideration of the practicability of various possible control measures. At the present time it is unlikely that the African farmer would be able to spray his own crops efficiently, nor in many cases would he be able to afford to employ contractors to do this work. Although there are some varieties such as Natal Common and Valencia Bunch commonly grown by Africans which are extremely susceptible to damage by leafspot, the great majority of locally growns trains appear to be much more resistant, judging by their ability to retain leaf under leafspot attack.

Two *minor leafspot diseases* that have been recorded are produced by species of Phyllosticta and Pseudoplea. These diseases are of sporadic occurrence and do not spread appreciably.

Minor Diseases

Diseases of the aerial parts. The fungus *Sclerotium rolfsii* Sacc. can attack most parts of the groundnut plant. In the form of a thread blight, in which it has been recorded in Northern Rhodesia [1], it attacks leaves; it is also recorded locally as the causal agent of a root rot. In the United States [4] damage to pods and pegs has been reported, and also in Northern Rhodesia. The mature kernels are subject to a form of discoloration known in America as blue damage [4]. The discoloration is superficial and is produced by a reaction between materials in the testa and metabolic products of the fungus diffusing from the pod. The fungus itself is not usually found in the discoloured areas. Blue damage does not affect the value of the kernels as food or as a source of oil. As a result of these blemishes, however, a consignment may suffer in price. Blue damage is of fairly frequent occurrence in Northern Rhodesia, particularly when moist conditions prevent rapid curing and the kernels remain in the pods for a long time. Local practice is to shell groundnuts soon after lifting, which definitely reduces damage from this source.

A more serious form of curing damage is 'concealed damage', also described from the United States and occurring in Northern Rhodesia. It does not appear to be so serious locally as in America, probably on account of the local practice of shelling groundnuts soon after harvest; if shelling is delayed appreciably damage is often apparent. In the variety-collection material in which shelling cannot be done immediately, this damage is noted, especially in alternately branched varieties. The sequentially branched Spanish and Natal groups do not seem to be affected. This damage is well named, because it is only apparent when the pod is opened. The colour of the affected kernels varies from yellow to black and the oil in the cotyledons becomes rancid. *Corticum solani* (Prill and Delacr.) Bourd and Galy. has been isolated from locally grown diseased kernels. Elsewhere Diplodia species have been isolated. It seems likely that a number of fungi can bring about this disease, singly perhaps, or

in combination. It is difficult to obtain precise information on the primary cause of the disease, as numerous saprophytic and weakly parasitic species can be isolated from diseased kernels. Rapid curing reduces the incidence of this disease in America, and could be employed in large-scale cultivation locally if it were proposed to stack haulm with attached pods for any length of time.

Bacterial wilt, Pseudomonas solanacearum (E.F. Sm.) Dowson, occurs locally on groundnuts, but is seldom responsible for large-scale losses. It is sometimes more noticeable on new land than on land which has been in cultivation, especially to cereals. Attacked plants wilt rapidly, the xylem tissue is stained brown, the roots die and decompose. Some adventitious roots may form above the decomposed root section, sometimes sufficient to enable the plant to survive. More frequently the plant wilts rapidly and dies. In the prevailing climatic conditions and at the elevations found in Northern Rhodesia (3,000–5,000 feet above sea-level), there is at present little apparent tendency for the disease to build up over the seasons.

Seedling rots. The use of seed dressings to control seedling and pre-emergence rots is a routine practice with some of the more progressive farmers. Organo-mercurials were used at first, but more recently the sulphur-based material T.M.T.D. has been used in the commercial forms available. Most seed is hand-shelled and seed dressing can be regarded as an additional insurance against early losses of stand. With the expected increased use of machine shellers this practice will become of greater importance. Gibson [12] has shown that the use of T.M.T.D. in seed dressings controls *Aspergillus niger* Van Tiegh, the cause of crown rot. The organo-mercurials did not control this fungus but rather tended to favour it by controlling competitor species.

Nutrient deficiencies. A condition which is not strictly a disease but a deficiency which has been noted in some areas of Northern Rhodesia is that termed 'pops' by the Americans. Preliminary pot trials have indicated that deficiencies of calcium and boron can produce this condition (J. B. M. Vogt, unpublished data). In the developing pod the embryos abort, with the result that an apparently normal pod is produced which contains no seeds. The occurrence of the deficiency varies in form; in some instances whole fields may produce little but empty pods; in others it may occur in small patches or even single plants. Work on this problem is continuing.

Conclusion

A striking feature of groundnut disease incidence in Northern Rhodesia is that in local cultivation diseases are not very serious. The result has been that disease problems were underestimated in large-scale experimental plantings. Local practice is certainly susceptible of improvement; for instance, by the destruction of 'volunteer' groundnut plants. The value of early planting in minimizing some diseases, e.g. rosette, is appreciated in some areas by Africans but not in others. By cumulative

experience the African, without awareness of the fact, is achieving substantial control of disease by traditional practices.

Cultivation of groundnuts on an extensive scale requires careful planning to avoid disease complications. There are indications as to how this may be achieved.

Continued observation will be necessary to ensure that effective control is being maintained, especially in changing circumstances. Further control measures may be necessary to meet changed conditions following the development of more advanced African agricultural systems.

Acknowledgements. Thanks are due to Messrs. A. N. Prentice and A. Angus for help in preparing this paper and to the Director of Agriculture, Northern Rhodesia, for permission to publish.

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(*Received 10 October 1959*)

THE NGUNI BREED OF CATTLE[1]

III. YIELD AND COMPOSITION OF MILK; HAEMOGLOBIN AND PHOSPHATE BLOOD LEVELS; COAT COLOUR AND SKIN CHARACTERISTICS

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WITH PLATE I

Summary

Yield and composition of milk. Three lactations for 1951, 1952/3, and 1953/4 for Nguni cows are reported, and the yields are shown to have been influenced considerably by the system of management, where:

(*a*) Calves ran with their dams during the day and were also introduced at milking time; and

(*b*) calves were introduced at milking time only.

The mean daily residual milk yield for (*a*) was 2·93 lb., and that for (*b*) was 5·59 lb. These figures apply to the latter stages of the lactation period of ten cows, and it is to be expected that intramammary pressure would have exercised a stronger influence in the earlier stages of lactation.

The mean daily yield per cow in 1951 was 2·60 lb. (mean lactation period 271 days); in 1952/3 it was 3·14 lb. (260 days); and in 1953/4 it was 4·08 lb. (197 days—incomplete), with 72, 35, and 15 cows respectively.

Analyses of Nguni milk from April to October 1951 gave a mean of 4·38 per cent. butterfat and 9·21 per cent. solids-not-fat. Using milk collected over the months August to October 1951, the following results were obtained: total dry matter, 12·65 per cent.; ash, 0·73 per cent.; protein, 4·02 per cent.; chloride, 0·11 per cent. Cl; calcium, 137 mgm. per 100 ml.; pH, 6·35.

These figures apply to milk collected in the latter 3 months of the lactation period and refer to herd milk.

Haemoglobin and phosphate blood levels. Analyses of Nguni and Crossbred blood to determine inorganic phosphate and haemoglobin levels of different age groups show that cows had a low blood phosphate content (5·83 mgm. per 100 ml. blood) compared with heifers (9·04 mgm. per 100 ml. blood). Haemoglobin content remained relatively constant, ranging from 10·82 to 12·15 gm. per 100 ml. blood for the Ngunis and the Crossbreds. There was no breed difference.

Coat colour and skin characteristics. Colour distribution data indicated that the nkone blacks (19·1 per cent.) and the nkone reds (11·6 per cent.) were the most predominant colour patterns for the Nguni breed, whereas among the Afrikaner × Nguni crossbreds (F1), red (32·3 per cent.), nkone red (18·8 per cent.), and black (11·3 per cent.) were the predominant colours. In the three-quarter-bred group, the reds predominated. Colour would not appear to have had much effect on growth (i.e. up to 30 months of age), except in the case of red *v.* black nkone, where the red-coloured group tended to be significantly heavier than the black nkone group. Low group numbers and the high coefficients of variability, however, do not allow much importance being attached to this result.

Skin thickness increased with age and there was very little breed difference between age groups. Nguni cows appear to have thinner skins than the Afrikaner cows on Mpisi.

[1] Parts I and II of this series were published in earlier numbers of this Journal [1, 2].

[Empire Journ. of Exper. Agric., Vol. 29, No. 113, 1961.]

Yield and Composition of Milk from Nguni Cows

One hundred Nguni cows, of varying ages, selected from the general Mpisi herd as having a 'milky' conformation and rearing their calves well, were utilized in the milking trials. All cows had calved between mid-October and mid-January. Milk recording started at the beginning of January 1951.

Butterfat and solids-not-fat (S.N.F.) were determined once a month for each cow over most of the lactation period. Samples of herd milk, treated with cresol as a preservative, were used for determination of total solids, ash, protein, chloride, calcium, and pH.

In 1951 the cows and their calves were allowed out in the camps daily from about 7 a.m. to 4–5 p.m. At night the cows were kept in a small camp (overgrazed) near the homestead while the calves were kraaled next to the milking sheds. Milking took place from 5.30 to 6.30 a.m. after each calf had suckled its own dam. After thus stimulating milk flow, the calf was not allowed to suckle again until the udder had been almost milked out. The calves were then allowed to associate with their dams again in the camps and could suckle at any time until they were kraaled in the evening. No supplementary feeding was given.

The effect of the system of calf management on the milk yield was studied. Starting from 19 October 1951 the ten highest milkers were milked each day for 33 days longer than the remainder of the milking herd (exceptionally low yields by Nguni standards necessitated the cessation of milking of the remainder of the herd). The calves of the ten cows thus retained were allowed to be with their dams only at milking time, when they stimulated milk flow prior to hand milking. In effect, two successive 'treatments' (i.e. systems of calf management) were carried out on the same cows.

Milk records were also collected for cows milking for 150 days or more during the periods November 1952 to September/October 1953 and November 1953 to the end of May 1954.

Results and Discussion

Milk yields. Fig. 1 shows the lactation curve of the Nguni under the conditions prevailing at Mpisi. The level of nutrition had a major influence on milk yield, since lack of rain would cause veld growth to cease, followed by a decline in daily yields.

As far as the reliability of the yield figures is concerned, there is a great deal of variation arising from the fact that the majority of cows comprising the dairy herd had already calved down 4–8 weeks prior to the commencement of hand milking on 2 January 1951, and had, no doubt, adapted themselves to their calves' requirements. (Wallace [3], working with milk yields of sheep, concluded that ewes adjust their yields, over the first 2–3 weeks after parturition, according to the demands of the lambs.) Furthermore, the calves were free to suckle their dams from after milking in the morning to the time they were kraaled in the evening, and thus no true idea of the actual milk secreted by the cow can be obtained under the conditions of this test. Fig. 2 bears this

out, even though the calves were still introduced at milking time to effect milk-flow.

When the calves were used only to stimulate the let-down of milk, the recorded milk yield practically doubled itself in all cases. The mean daily yield per cow increased from 2·93 to 5·59 lb. This increase of

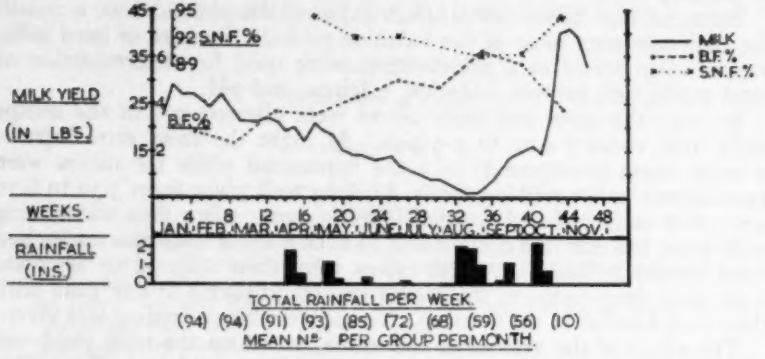

FIG. 1. Mean weekly milk yields per cow. Showing mean B.F. and S.N.F. tests per cow per month and indirect effect of precipitation on yield. (Jan.–Nov. 1951.)

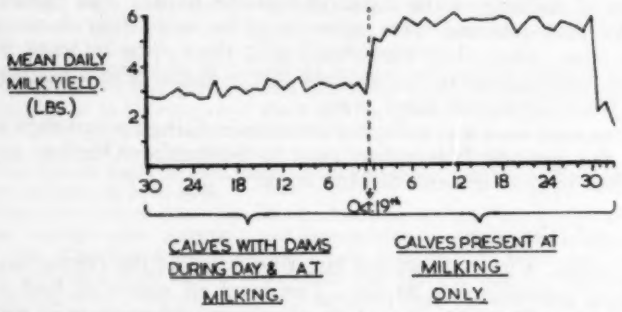

FIG. 2. Mean daily milk yields of ten Nguni cows. (Showing the effect of two 'Treatments' on yield.) (Stage of lactation 8–8½ months.)

2·66 lb., due to change in the management of calves, is statistically highly significant ($P = 0{\cdot}01$) for each of the cows, in favour of the second period, when the normal lactation curve of any milk cow begins to decline steeply.

Whether the same relationship holds at the height of the milk-flow remains to be tested, since intramammary pressure would then exert a greater retarding influence on milk production. The effect of frequent sucklings during the course of the day reduces the pressure on the alveoli, thereby enhancing milk secretion [4]. The calf, in effect, has access to a greater potential milk quantity during the 12-hour period

with the cow than would be the case if allowed to suckle only at the end of the 12-hour period.

The rainfall was reasonably good over the whole period prior to and during which the milk yields were compared.

The yields in the second period give a much fairer indication of the milking propensities of the Nguni at 8½ months, and are much more in keeping with the evidence that the Nguni is able to produce on an average 'about 2 gallons per day off the veld when in full milk flow. Certain Native owners (in Zululand) claimed that some of their cows yielded up to 3 gallons a day' [5]. Unfortunately the Zulu and Swazi are not as accurate as could be wished and yields of up to 3 gallons a day must be treated with scepticism until strict milk-yield recordings of the Nguni are forthcoming. The highest production for any one month by any one cow at Mpisi occurred in January 1951, when a total of 312 lb. of milk was recorded, averaging just over a gallon daily. This cow (No. 272) calved on 17 December 1950 and was obviously in full milk-flow. Unfortunately illness affected her total recorded production, but excluding that period, she still averaged 4·4 lb. of milk daily over 276 days. Assuming that the calf consumed about half the total milk secreted, as indicated by Fig. 2, an average of approximately 9 lb. daily at 8½ months lactation is good when compared with 8–9 lb. for all milk cows in Natal [6].

Table 1 summarizes the results of three lactation periods for Nguni cows on Mpisi:

TABLE 1

Mean Total Milk Yields of Nguni Cows Lactating for more than 150 Days

No. of cows	*Mean total yield per cow (lb.)*	*Mean lactating period (days)*	*Yield per cow per day (lb.)*
Jan. to Sept./Oct. 1951			
72	702	271	2·60
Nov. 1952 to Sept./Oct. 1953			
35	819	260	3·14
Nov. 1953 to May 1954 (incomplete)			
15	802	197	4·08

An increase in the mean daily yields per cow for 1952/3 and 1953/4 over that in 1951 is apparent, but the lack of information for the remainder of the lactation periods for cows in 1953/4 tends to give a higher value than the 'normal' yield for the whole period.

The lengths of the lactation periods in the majority of cases are favourable, considering that no selection had taken place for quantity, quality, persistency, or duration of lactation.

Supplementary feeding, e.g. hay, during periods of protracted droughts, would help to maintain a relatively high level of production throughout the lactation period of Nguni cows. It is well known that proper nutrition allows the maximum expression, under the limitations

imposed by a given climate, of the genes for milk production, thereby being an aid to selection.

It is of interest to mention that three Afrikaner cows were milked for short periods but would appear to have been intractable since their milking was discontinued. The average yields from these cows A5, A17, and A31 were 3·68 (for 78 days), 4·05 (for 20 days), and 3·81 lb. (for 30 days) per diem respectively.

A Nguni × Jersey F1 cow (No. 689), the product of an accidental mating, over a period of 208 days yielded 1065·4 lb. averaging 5·12 lb. daily for her first lactation.

As far as can be ascertained, the incidence of mastitis is low in the Nguni breed and can, most probably, be explained by the fact that they are low yielders and have small udders.

That the Nguni is amenable to being milked is shown by the fact that of the original 103 cows brought in as milking cows, only eight were rejected as intractable. J. S. Murray (personal communication) doubted whether the cows could be milked without their calves at hand, this being based on trials carried out at Vuma in Zululand. However well based this opinion might be, it is believed that the training of docile first-calvers from the start could lead to management practices being employed with Nguni cows similar to those used with commercial dairy herds.

Boyns [7], reporting on Sudanese cattle, mentions that a saving of approximately ten pounds of milk daily was effected by training the cows to let down the milk without the presence of their calves. Williams and Bunge [8], working with Bukedi cattle in Uganda, mention that heifers were trained to milk without their calves, with initially disappointing results, but eventually forty-two out of fifty were trained and this is now the normal practice at Serere, failures being rare.

There is a common belief among the Swazi and the Zulu people that the black nkones are the milk type and the red nkones the beef type. In comparative studies between the two 'types', this statement appears to be ill founded, since J. H. R. Bisschop (unpublished report) stated: 'I compared the black and red nkones with each other, but did not find that the first was more milky or the second more beefy.'

Composition of Nguni milk: butterfat and S.N.F. Because the calves ran with their dams during the day and then were allowed to suckle again prior to milking, no great reliability can be attached to figures for butterfat and S.N.F. It is well known that the last portion of milk from the udder is richest in butterfat. Hence, should the let-down stimulus be of short duration, the calf would receive all the richest milk, as well as that lowest in butterfat suckled prior to hand milking. It cannot be assumed that the middle portion of milk secreted would be representative of the whole. Several of the milkers were trainee cattle-guards, who were switched from job to job after a suitable period. This, too, would tend to detract from a consistent milking routine.

The mean monthly tests of the whole milk herd, for butterfat and S.N.F., are shown in Fig. 1.

The mean butterfat of Nguni milk recorded over the period April to

October was 4·38 per cent. (S.E.±1·65), i.e. 33·4 lb. butterfat from 762·9 lb. of milk, the range being 1·20 to 10·30 per cent. This latter figure applies to those cows towards the end of their lactation when the recorded daily milk yield was in the vicinity of 1 to 2 lb.

Breed averages are shown in Table 2 for American cows, while Richmond and Davies, mentioned in [9], have recorded 3·75 and 3·67 per cent. as averages for butterfat, for cows (predominantly Dairy Shorthorn) in England. Bakalor [10], working on Pretoria milk, mentions 3·59 per cent. butterfat as the average. Thus, as is to be expected, Nguni milk is richer in butterfat than the average for dairy cows (excluding the Channel Island breeds). The herd average for Kenana cows at the Gezira Research Farm in the Sudan was reported as being 5 per cent. butterfat (individuals up to 7 per cent.) [11].

TABLE 2

Butterfat and S.N.F. Percentages of the Milk of Dairy Breeds in America (Caulfield *et al.*—quoted in [9])

	S.N.F.	*B.F.*
Holstein	8·52	3·69
Ayrshire	8·91	4·32
Guernsey	9·29	5·09
Jersey	9·54	5·53

TABLE 3

Summary of Analyses of Nguni Milk (Aug. to Oct. 1951)

No. of cows (range)	*Total D.M. %*	*Ash %*	*Protein %*	Cl %	Ca *mgm/100 ml. milk*	*pH*
10–68	12·89	0·73	4·01	0·11	137	6·36

The mean S.N.F. test for the Nguni milk declined over the dry months (i.e. winter) and rose apparently when nutrition level increased.

Based on the calculated total of 66·3 lb. S.N.F. in 719·2 lb. of milk, the mean S.N.F. content was 9·21 per cent. (S.E.±1·00).

The mean S.N.F. content of Pretoria milk is given by Bakalor [10] as 8·59 per cent., much lower than that for the Nguni over the test period. Richmond's average for S.N.F. in England was 9·00 per cent. [9]. Red Sindhi cattle in India have an average S.N.F. content of 8·50 per cent.

Other constituents. Table 3 gives the combined results of the analyses carried out on samples of Nguni milk in 1951.

Total dry matter. The mean, 12·89 per cent. (S.E.±0·87), is comparable with overseas figures 12·69 to 12·75 [9], but is higher than Bakalor's figure [10] for Pretoria milk—12·17 per cent.

Ash. Figures (per cent.) reported for dairy cows: 0·70 [12] and 0·73 [9], are similar to that obtained for the Nguni, 0·73 (S.E.±0·12). For the milk of Red Sindhi cows in India an ash content of 0·75 per cent. is reported [13].

Protein. The crude protein percentage of the Nguni samples ranges from 3·80 to 4·21 over the months August to October, with a mean of 4·01. On the basis of total protein, i.e. 37·18 lb. in 925·1 lb. of milk, the protein content is 4·02 per cent. (S.E. ±0·15).

Comparing this figure with the average for milk from dairy cows (predominantly Dairy Shorthorn) in England, Nguni milk would appear to be higher in protein content. Richmond reports 3·20 and Davies 3·67 as the average for dairy cows in England [9].

Chloride. The mean of 0·11 per cent. Cl in Nguni milk (S.E. ±0·01) is lower than that reported by Richmond [9], who rates the average for English dairy cows as being 14 per cent. of the ash. Schneider *et al.* [13] have reported that Red Sindhi cattle had a mean chloride content of 0·08 per cent. Cl, which is lower than the figure for the Nguni and probably reflects different feeding conditions.

Calcium. The mean of 137 mg. (S.E. ±6·8) Ca per 100 ml. of milk applies to a range 126 to 146 mg.

pH. The hydrogen-ion concentration of the cresol-treated milk samples varied from pH 6·15 to 6·75, the mean being 6·35. Judkins and Mack [12] and Richmond [9] state that fresh milk has an acidic reaction varying between pH 6·5 and 6·7. The Nguni milk samples were thus generally somewhat more acidic.

The values for ash, protein, and total solids were not derived over exactly the same period as those for butterfat and S.N.F., nor do they represent the same group of cows throughout, which explains why the butterfat and S.N.F. total to somewhat more than the total solids. Nevertheless, being averages of the whole herd over the periods in question, they give a good idea of Nguni milk composition.

The suckling calves showed a gain in weight over the winter period as well as highly significant increases in body length and significant increases in height of withers. Growth was thus maintained at an increasing rate over the normally growth-depressing winter period. This can be attributed only to the ability of their dams to produce sufficient milk off the veld during the winter to meet the increasing demands of growth, and reflects to the credit of the dams in question. It is unfortunate that no data are available to express the growth of suckling calves during the early part of their lives in terms of pounds of milk produced. Such a figure, together with that for milk obtained by hand milking, would allow of a better assessment of the productivity of Nguni cows.

Haemoglobin and Inorganic Phosphate Blood Levels of Nguni and Afrikaner × Nguni (F1) Cattle

This study was undertaken at the Mpisi Experimental Station in Swaziland during June 1951 in order to obtain a clearer picture of different age groups of Nguni and cross-bred cattle in respect to certain blood constituents. There are also indications 'that haemoglobin determinations could be used as a guide in evaluating adaptability of the animals to given environmental conditions' [14]. Adapted animals, i.e. to the effects of high temperatures, were found to have a high

haemoglobin index, and those poorly adapted a low index. Blincoe and Burge [15] recorded that increasing temperatures over 85° F. caused the blood inorganic phosphorus level to increase.

Owing to the sub-tropical nature of the Mpisi climate, no unadapted animals, i.e. newly imported exogenous breeds, e.g. Hereford, Shorthorn, &c., were available to effect a local comparison under similar conditions.

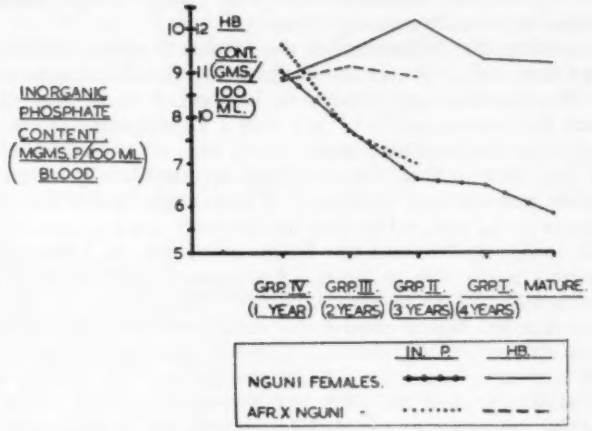

FIG. 3. The inorganic phosphate and heamoglobin content of Nguni and Afrikaner × Nguni blood. (Showing the relationship with age.)

Materials and Methods

Samples of blood were withdrawn from the jugular vein of groups of Nguni and Afrikaner × Nguni females. The groups were: Mature Group (over 5 years), Group I (approx. 4 years), Group II (approx. 3 years), Group III (approx. 2 years), and Group IV (approx. 1 year).

Each sample was placed in a bottle containing a small amount (approx. 1 part to 9 parts of blood) of 10 per cent. sodium citrate solution and was vigorously shaken to effect thorough mixing. These sample bottles were then tightly stoppered, and after shipment to Pietermaritzburg were refrigerated until the analyses were made.

Fiske and Subberow's method for the determination of inorganic blood phosphate was used, and in the determination of haemoglobin the method of Wong was followed [16].

Results and Discussion

The results are shown graphically in Fig. 3.

The clearest fact emerging from this graph is the relationship between inorganic phosphate and age. The older cows had a lower inorganic phosphate blood content than the heifers. Both the Nguni and Afrikaner × Nguni show this relationship to age. The haemoglobin content appears to increase up to a point (i.e. at 3 years) and then decrease and

level out as maturity is reached for the Nguni cattle, the crossbred animals showing the initial tendency less noticeably.

Hammersma [17], working at Onderstepoort on nine cattle varying in age from 15 to 27 months and of both sexes, noticed that the older animals had a lower haemoglobin level than the younger group. Fig. 3 does not bear this out although a tendency in that direction is noticeable in the older groups. In contrast to Hammersma's findings, the haemoglobin content of Nguni cattle increased from 1 to 3 years of age, although the increase was statistically non-significant.

On comparing the differences of the means of groups statistically by Student's t-test [18], it was found that none of the differences in haemoglobin levels, between age groups or between breeds, was significant except that the one-year-old heifers had a significantly lower level (at $P = 0{\cdot}05$) than the 'mature' cows.

Dukes [19] states that the cow has approximately 12·03 gm. of haemoglobin per 100 c.c. of blood. The average figure for all Nguni age groups is 11·54 gm., while that for the cows is 11·19 gm.

Holman [20] puts forward the figure of 11 gm. of haemoglobin per 100 ml. blood, applicable to 'several European breeds of cattle living in temperate zones of Europe and America'. This figure is only slightly lower than that for Nguni cows living under sub-tropical conditions.

Whether either haemoglobin or inorganic phosphate content can be associated with adaptation to climate, particularly where high temperatures prevail for part of the year, remains to be proved. More recent workers than Manresa *et al.* [14] have arrived at divergent results. Blincoe and Burge [15] state that the 'haemoglobin level was not influenced significantly by ambient temperature in the range 50–100° F'. However, these results apply to Jerseys and Holsteins. Arrillaga *et al.* [21], studying tropical environmental effects on beef and dairy breeds, obtained a blood haemoglobin average value of 6·9 gm. per 100 ml. of blood, and they say that such low values 'were not associated with climatic factors but may reflect possible nutritional deficiencies'.

The wider the difference in age between groups, the greater the difference in inorganic phosphate level, being high in the young animals and low in the older groups, the differences being statistically significant at $P = 0{\cdot}05$ and 0·001 respectively. The differences between the breed groups of the same age were non-significant in each case. Whether this means that Nguni and Afrikaner blood will both have more or less the same inorganic phosphate level, under Mpisi conditions, requires further testing.

Blincoe and Burge [15], working with Jersey and Holstein cows, found that air temperatures over 85° F. increased the blood inorganic phosphate level. Whether prolonged temperatures over 85° F. would affect inorganic phosphate level permanently has not been established, since only relatively short exposures were used. These workers conclude that 'it appears from the literature that age, season, stage of lactation and food supply affect the inorganic phosphate level of blood'. Thus it appears wholly unlikely that inorganic phosphate levels in particular can be used as an index of adaptability.

Some Coat Colour and Skin Characteristics of Nguni Cattle

The whole colours and colour patterns of Nguni, Nguni × Afrikaner (half-bred), and Afrikaner ($\frac{3}{4}$) × Nguni ($\frac{1}{4}$) cattle were extracted from the Mpisi herd book, and embrace 1,501 Ngunis, 186 Crossbreds, and 46 three-quarter-breds (i.e. foundation cows and all calves born since 1945 to the end of 1954).

Using monthly weights and knowing the colour and age of given Nguni cattle, an attempt to gauge the effect of coat colour on growth has been carried out. Regarding weight increases as an indication of an animal's adaptability, the different colours and colour patterns were compared at 6 and 30 months of age to see if colour alone had any enhancing effect on growth. The colour groups were compared by means of Student's t-test [22].

Skin thicknesses were also measured using five different age groups of Nguni females and two groups of crossbred females. These measurements were obtained by using a Hauptner micrometer on a double fold of skin.

Results and Discussion

The colour and colour pattern classification for the Nguni have been described in Part I of this series [1].

The nkone blacks (19·1 per cent.), the nkone reds (11·6 per cent.), black and whites (7·7 per cent.), mpungas (7·3 per cent.), and the red and whites (5·9 per cent.) were the predominant colours and colour patterns of the Nguni on Mpisi. This predominancy changes on introduction, by crossbreeding, of Afrikaner blood where red (32·3 per cent.), nkone red (18·8 per cent.), black (11·3 per cent.), red and white (9·7 per cent.), and brown (5·4 per cent.) were the most frequently occurring colours and patterns. Although their number is particularly small in the case of the three-quarter-breds, the tendency is for the reds to predominate, showing the influence of the red Afrikaner sires in both the half- and three-quarter-bred stock.

Riemerschmid [23], Bonsma [24], Bonsma and Pretorius [25], and other workers have stressed the importance of coat colour in the tropics and sub-tropics. With this in mind, colour groups were compared on the basis of weight for age, the results appearing in Table 4.

At 6 months of age, no one group shows any weight superiority over another, as would be expected at such an early age. At 30 months of age, where the effect (if any) of coat colour should begin to be manifested, there are no significant differences except in one instance: the red nkone group is significantly superior (at $P = 0{\cdot}05$) in weight to the black nkone. The small numbers in each group would tend to introduce a greater source of variation than would otherwise have been the case. Also, each age group is composed of different individuals so that the genetic variation would be greater than would be the case if the same animals were used in comparison at 6 months and again at 30 months. The coefficients of variation tend to be high throughout.

The results of skin thickness measurements recorded on 5 September 1951 appear in Table 5.

TABLE 4

Mean Weights of Different Colour Groups of Nguni Heifers (from Mpisi records)

		Red and white	*Black and white*	*Red*	*Black*	*Black Nkone*	*Red Nkone*	*Red*
6 months of age	Mean wt.	268·3	268·5	274·3	255·7	254·3	258·5	258·2
	No. in sample	15	19	15	16	36	40	18
	Coeff. var. %	10·5	16·1	17·5	15·0	12·7	17·6	15·4
30 months of age	Mean wt.	655·8	640·2	677·8	646·4	615·8	656·1	655·6
	No. in sample	14	15	12	10	30	24	7
	Coeff. var. %	14·3	13·0	12·2	10·3	14·8	12·9	10·7

TABLE 5

Skin Thicknesses of Different Age Groups of Nguni and Crossbred Females (in millimetres)

NGUNIS

Year of birth	*Group IV (1950)*		*Group III (1949)*		*Group II (1948)*		*Group I (1947)*		*Cows (mature)*	
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
No. in group . .	24	24	61	61	61	61	35	35	45	45
Mean . . .	3·2	5·3	3·7	5·9	4·4	6·6	4·2	6·4	4·1	6·1
Coeff. var. % . .	17·7	19·9	11·4	12·7	9·2	13·3	11·7	10·6	20·0	22·6

CROSSBREDS

Year of birth	*Group III (1949)*		*Group II (1948)*	
	a	*b*	*a*	*b*
No. in Group . .	16	16	12	12
Mean . . .	3·5	5·8	4·5	7·3
Coeff. var. % . .	15·9	17·9	8·5	7·5

a = shoulder thickness, mean of all Nguni groups = 3·9 mm.
b = rib thickness, mean of all Nguni groups = 6·1 mm.

As is to be expected, skin thickness increased significantly with age up to Group II. Comparing the two crossbred groups with the Nguni groups, the only statistically significant difference (at $P = 0{\cdot}01$) is between the Group IIs, in the region of the rib.

In view of the small number of Afrikaner cattle on Mpisi, no statistical comparisons can be made; however, the average for three Afrikaner females (Group II) and four Afrikaner cows (mature) were, for shoulder and rib measurements, 4·01 and 6·1, and 4·6 and 6·2 mm. respectively. Both the Nguni and the Afrikaner × Nguni Group IIs had

'Lomjozo'—Nguni cow classified as a 'good' milk producer. She produced 1,174 lb. milk in 320 days.

thicker skins than the Afrikaner Group IIs. For the Nguni cows, the average is less than that of the Afrikaner cows. Zebu cattle in Tanganyika and Kenya are reported as having skin thicknesses of shoulder: 2·6 and 3·7 mm. respectively, and 13th rib: 3·9 and 6·5 mm. respectively for the two territories [26]. This difference may be due either to difference in climate or difference in Zebu breeds.

Acknowledgements. The writer wishes to express his indebtedness to Prof. C. W. Abbott of the University of Natal and the Swaziland Veterinary Department, in connexion with his studies of milk yields and composition; and to Dr. J. Schuss of the Swaziland Veterinary Department, and Dr. G. V. Quicke of the Biochemistry Department of the University of Natal, for help received in his studies of blood composition.

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(*Received 12 August 1957; revised June 1960*)

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